

**Rotenberger Wildlife Management Area Initial Evaluation of  
Hydropattern Restoration  
Final Report**

Prepared for Florida Department Protection Agency  
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## Executive Summary

The Rotenberger Wildlife Management Area (RWMA) (**Fig. 1**), part of the northern Florida Everglades, is an extensively degraded 29,120 acre marsh. Historic landscape patterns and reports indicate the northern portion of the RWMA area was a sawgrass (*Cladium jamaicense*) dominated community while the southern portion was a ridge and slough community. Since the 1950s the RWMA has been cut off from surface water inflows and only received direct rainfall (SFMWD, 2001). As a result, the RWMA has experienced marked disturbances such as increased drainage, decreased hydroperiod, drought, and fires, resulting in an increase and transition to upland vegetation species, and impacted areas facilitating the need for hydropattern restoration.

An interim hydropattern target was established using the Natural System Model (NSM) to predict monthly stage targets based on a 31-year calibration period to minimize the potential for excessive dry out during the dry season (approximately October through May). While a 1983 Memorandum of Agreement outlining the restoration plan for the RWMA specified in general terms the need to manage this system in a manner that attempts to restore and preserve natural Everglades habitat, a specific ecosystem restoration target (i.e. defining the target habitat and specific vegetation cover) for the RWMA has not yet been established. However, the STA-5 discharge Permit No. 0131842, requires the District to monitor downstream receiving areas, such as RWMA, in order to assess for any ecological effects of discharge.

Rainfall was the main source of water into the RWMA during the pre-discharge period (November 1997 through June 2001). The internal stage gauge readings indicated the system had no standing water much of the year, resulting in a shortened hydroperiod that promoted the growth of several species indicative of drier habitats. Data collected during this period support that the RWMA was an impacted wetland trending toward an upland area and that changes in operation and management of this area were needed to ensure the protection of this area's natural resource value.

Post-discharge period (July 2001 through June 2003) data indicated a significant increase in hydroperiod, from 3 to 7 months, and was further supported in a doubling of the mean water depth from 0.4 ft during the pre-discharge period to 0.8 ft during the post-discharge period. Preliminary analysis has indicated that in addition to natural factors,

such as below average rainfall, evapotranspiration rates, and seepage, the opening of the G-402 outflow structures when stages reach 12.3 ft was a contributing factor that led to a decrease of water depth and not attaining the NSM target stages. However, the comparison of the monthly mean stage levels during the pre- and post-discharge periods (**Figs. 2** and **9**), clearly indicates that the system is trending toward hydropattern restoration, most likely increasing soil moisture and decreasing the possibility of soil loss through muck fires. Furthermore, this increased hydroperiod period during the post-discharge period resulted in the increase of obligate wetland species such as cattail (*Typha* spp.) and sawgrass. Cattail and sawgrass were the dominate vegetation present, collectively representing about 70 to 75% of the RWMA, while a mix of grasses and facultative wetland species inhabited the remainder of the area.

Preliminary analysis of the surface water quality samples collected during the post-discharge period show that total phosphorus (TP) concentration levels near the inflow (mean of 0.056 mg/L) were elevated relative to G-402 outflow TP concentrations (mean of 0.033 mg/L). Therefore, continued monitoring of the system is recommended to assess if this is a temporary and/or spatially stationary condition or indicative of a moving front.

## **Introduction**

The Rotenberger Wildlife Management Area (RWMA) (**Fig. 1**), part of the northern Florida Everglades, is an extensively degraded 29,120 acre marsh. Historic landscape patterns and reports indicate the northern portion of the RWMA area was a sawgrass (*Cladium jamaicense*) dominated community while the southern portion was a ridge and slough community. Since the 1950s the RWMA has been cut off from surface water inflows and only received direct rainfall (SFMWD, 2001). As a result, the RWMA has experienced marked disturbances related to increased drainage, decreased hydroperiod, drought, and fires, resulting in an increase and transition to upland vegetation species indicative of high nutrient, impacted areas. Therefore, the RWMA was identified for hydropattern restoration in accordance with the 1983 Memorandum of Agreement with the Florida Department of Environmental Protection (FDEP) and Florida

Fish and Wildlife Commission. In an effort to accelerate hydropattern restoration, the South Florida Water Management District (District) has adopted a phased approach and began diverting discharges from the Stormwater Treatment Area 5 (STA-5) into the RWMA through the G-410 inflow structure in July 2001. An interim hydropattern target was established using the Natural System Model (NSM) to predict monthly stage targets based on a 31-year calibration period. Predictions of the NSM have the following revisions: a) when the average NSM depth drops below ground, the base is set to ground level, and b) to minimize the potential for excessive dry out during the dry season (approximately October through May), a 0.25 ft offset was added to the target stage to obtain the interim operational schedule (**Fig. 2**). While a 1983 Memorandum of Agreement outlining the restoration plan for the RWMA specified in general terms the need to manage this system in a manner that attempts to restore and preserve natural Everglades habitat, a specific ecosystem restoration target (i.e. defining the target habitat and specific vegetation cover) for the RWMA has not yet been established. However, the STA-5 discharge Permit No. 0131842, requires the District to monitor downstream receiving areas, such as RWMA, in order to assess for any ecological effects of discharge.

The monitoring and research program was implemented two years prior to discharge into the RWMA and was designed to assess not only the success of hydropattern restoration and the ecological effects of inundation, but also to document the pre-discharge ecology of the ecosystem. Additionally, the information will provide decision-makers with the ecological data needed to implement sound environmental management decisions that will aid in the restoration of the Everglades.

This report summarizes the results of data collected prior to and following the date of first discharge of STA-5 (July 2001). The pre-STA discharge (pre-discharge) period extends from November 1997 through June 2001 and post-STA discharge (post-discharge) period extends from July 2001 through July 2003. Additionally, two previous interim reports (Smith *et al.* 1998; Smith *et al.* 2000) describing the pre-discharge period are available on the District web site at [www.sfwmd.gov](http://www.sfwmd.gov).

## Study Area

The RWMA (**Fig. 1**) encompasses 29,120 acres within the Everglades Agricultural Area (EAA) and is located immediately north of WCA-3, west of the Miami Canal and 17 miles south of Lake Okeechobee. Currently, the RWMA contains remnant sawgrass and tree island communities that are transitioning into monospecific stands of cattail (*Typha domingensis*) and in the case of the tree islands, undergoing severe soil subsidence. In addition, upland classified vegetation is widespread throughout much of the area. Inflow into the RWMA is through the G-410 pump structure located in the southern reach of the STA-5 discharge canal. Outflow from the RWMA is through the G-402 (A-D) structures, a set of gated culverts that discharge into the Miami Canal. Mean water levels internal to the RWMA are determined from two District monitored stage gauges Rotenberger North (Rott.N) and Rotenberger South (Rott.S), with a base elevation of 12.05 NGVD assumed for the entire area.

## Methods

The entire period of record for this report extends from November 1997 through June 2003 and is split into two distinct operational periods: pre- and post-discharge. Pre-discharge extends from November 1997 through June 2001 and represents that period when the majority of water received by the RWMA was direct rainfall. Post-discharge extends from July 2001 through June 2003 and encompasses the period when the RWMA received not only direct rainfall, but discharges from STA-5 through the G-410 inflow structure.

Two monitoring transects were established in the northwestern section of Rotenberger in 1997. Both transects extend in a southeasterly direction away from the inflow G-410 structure towards the marsh interior (**Fig. 1**), and were oriented parallel to the expected direction of flow. The northern transect travels in a more easterly trajectory toward the G-402A outflow structure, while the southern transect trends more toward the G-402D structure. Five sample points were established at 0.25, 0.5, 1.0, 2.0, and 4.0 km along each transect in an effort to detect any nutrient gradient that may develop as a result of STA inflow. Wooden sampling platforms were established at each site to facilitate sample collection. Sample locations along the northern transect were designated as

N0.25, N0.5, N1.0, N2.0, and N4.0, with N0.25 being located closest to the inflow structure and N4.0 being positioned farthest from the inflow. The southern transect site nomenclature was similar with S0.25, S0.5, S1.0, S2.0, and S4.0 representing the sample locations.

### Hydrology

During the period of this report (November 1997 through June 2003), the RWMA received water through direct precipitation, emergency supplies from the Miami canal to extinguish muck fires, and inflows through the G-410 structures resulting from STA-5 discharges. Inflow volumes into the RWMA were calculated at the G-410 using a calibrated pump equation along with head and tail water measurements (SFWMD, 2004). Outflow volumes were calculated through the four outflow structures (G-402A through G402D) using a calibrated box-weir equation.

Internal stage levels were recorded at two locations, one situated in the northern portion of the RWMA (Rott.N) and the other located in the southern area (Rott.S) (**Fig. 1**). Stage levels were remotely monitored every 15 seconds, means compiled and transmitted via radio to District headquarters every 15 minutes. Internal stage was reported as monthly means derived from daily averages of Rott.N and Rott.S. Nominal water depths were calculated as the daily mean stage minus the mean base elevation of 12.3 ft NGVD. This elevation was based on the assumed base elevation of 12.05 ft NGVD for the RWMA in addition to a 0.25 ft offset. Monthly site measurements of actual water depth were recorded at each sample site using a meter stick. Hydroperiod was defined as the length of time standing water occurred and was calculated using the nominal water depths.

The yearly hydropattern restoration target for the RWMA was based on the monthly target stage elevations determined by the NSM model, which was calibrated using a 31-yr basin flow data set (1965-1995) (**Fig. 2**). Monthly mean pre- and post-discharge stage levels were compared to the NSM target stage levels to determine when hydropattern restoration was achieved.

### Water quality

When sufficient surface water was present ( $> 10\text{cm}$ ), surface water samples were collected monthly from the north (upstream) side of each sample site using a peristaltic pump. Grab and composite water samples at the RWMA inflow and outflow structures were collected intermittently when the system was either receiving or discharging water. The samples collected at the inflow and outflow structures were analyzed for total phosphorus (TP) concentration levels, while the samples collected at the internal sites were analyzed for 18 parameters (**Table 1**), excluding the physical parameters measured with the Hydrolab® water quality multi-probe. All sample collection and analyses have been conducted in accordance with either U.S. Environmental Protection Agency (USEPA, 1993) or American Public Health Association (American Public Health Association, 1989) approved analytical methods. The samples were stored in coolers on ice during collection, transport, and overnight shipment to the Florida Department of Environmental Protection (FDEP) laboratory for analysis.

Porewater was sampled via *in situ* wells located at the upstream end of each monitoring platform at a depth of 0 – 10 cm. Water depth measured near the well was used to calculate the appropriate volume of water purged to ensure a clean sample. All samples were placed in coolers on ice during field collection and transport, and shipped overnight to FDEP for analysis of water quality constituents (**Table 2**). All sample collection and laboratory analysis were in accordance with the previously described protocol.

### Soil Properties

Soil cores were collected annually within 50 meters of each monitoring platform. Each core was sampled using a 10-cm diameter coring device to a depth of 20 cm. Three replicate cores per station were taken and each core sectioned into three layers, 0-2, 2-10 and 10-20 cm. The soil cores were sectioned in the field, placed in bags and packed in coolers with ice. All samples were shipped on ice to DB Environmental Labs, Florida for nutrient analysis.

### Periphyton

Periphytometers, containing glass slides as the artificial substrate, were deployed for about 4 weeks at each monitoring site during the late portion of the wet season (October and November). Upon retrieval, the periphytometers were processed in the lab and subsampled for taxonomic, chlorophyll *a*, and biomass analysis. The taxonomic subsamples were preserved then shipped to the FDEP laboratory for taxonomic analysis. Biomass and chlorophyll *a* analysis were performed at the District. Biomass measurements were obtained by drying subsamples at 60°C for 3 days and weighing the dried samples. Ash-free dried weights were obtained by placing the subsamples in a muffle furnace at 500°C for one hour then re-weighed. Chlorophyll *a* amounts were analyzed using a fluorometer. Additionally, if present, floating and epiphytic periphyton samples were collected from each sample site during the wet season, and referred to as grab samples.

#### Emergent Macrophytes

Tissue samples from the sawgrass and cattail vegetation species were collected twice a year, during wet and dry seasons (1 November to 30 April) from three sites (0.25, 1.0 and 4.0 km) at each transect. Three replicates of live leaves and roots for each species per site were analyzed for total phosphorus (TP mg/kg) and total nitrogen (TN mg/kg). All replicates were composite grab samples from several plants. Samples were oven-dried at 60° C for approximately five days then shipped to DB Environmental Labs for nutrient analysis.

Aboveground biomass was collected annually from randomly selected 0.25 m<sup>2</sup> quadrants at each site in the north and south transects (0.25, 1.0 and 4.0 km sites). The vegetation was clipped at the soil surface and sorted according to dominant species type (sawgrass, cattail, other) and plant component (live leaves, dead leaves, other). All samples were oven-dried at 60° C for two weeks then weighed. Samples were not subsampled for nutrient analysis.

#### Statistical Analysis

Pre-discharge data (November 1997 through June 2001) are presented to describe the environmental conditions observed during this period. The system was dry during the

period extending from end of February 2002 to beginning of July 2002, resulting in no water quality samples available for analysis. All statistical analyses were performed using JMP version 5.0 (SAS Institute, 2000).

### **Pre-Discharge Period (November 1997 - June 2001)**

Several natural events occurred in the RWMA throughout the pre-discharge period. In 1999 two major extreme events affected the study area. In June a fire event burned the entire marsh with much of the northern portion experiencing muck fires, which was extinguished with emergency water deliveries from the Miami canal, and in November hurricane Irene brought higher than average direct rainfall amounts. During the period of 1999-2000, South Florida underwent a severe drought, while a tropical storm occurred in October 2000 resulting in greater than average rainfall to the RWMA.

### Hydrology

Direct rainfall on the RWMA totaled 161.69 inches providing 390,751 ac-ft of water, and was the predominant water source during the pre-discharge period (**Table 3**). In 1999 emergency water deliveries were made into the RWMA from the Miami canal in order to extinguish an extensive muck fire that was burning a large tract of land. However, neither inflow volumes nor phosphorus concentrations were measured during this event. The measured surface water depth ranged between below ground level to a high of 1.13 ft during 1999. In general, the hydrology during the pre-discharge period consisted of short hydroperiods (less than three months). The monthly mean stage level readings ranged from a low of 10.8 ft to a high of 12.9 ft (**Fig. 2**). These mean values were consistently below the NSM interim stage level targets set for the RWMA hydropattern restoration efforts ranging from 1.7 to 0.5 ft below the target, indicating the need for hydropattern restoration.

### Surface Water

Due to the extremely dry conditions within the RWMA during the pre-discharge period, surface water was only collected twice in 1998, six times in 1999 and two times

in 2000 out of 12 possible sampling events for each year. During the pre-discharge period there was no outflow from the system at the G-402 structures (**Table 3**). The mean surface water TP concentration during the pre-discharge period was 0.045 mg/L, with yearly means of 0.018, 0.085, and 0.033 mg/L in 1998, 1999, and 2000, respectively (**Table 1**). No spatial trend evident was evident in monthly mean concentration values for total phosphorus (TP), total dissolved phosphorus (TDP) or soluble reactive phosphorus (SRP) measured at both transects during the pre-discharge period (**Fig. 3**). With the exception of SRP, 1999 had the highest mean concentration for all measured phosphorus (P) variables during the pre-discharge period, but it also represented the year with the most sample collections (**Fig. 4**). **Table 1** provides the yearly means for the other analyzed parameters, while a complete table of means, standard deviations, minimum and maximum values can be found in **Appendix IA**. Additionally, box plots displaying the yearly mean concentration values for all measured parameters are presented in **Appendix IB**.

#### Porewater

Due to the extremely dry conditions within the RWMA during the pre-discharge period, pore water was only collected two, three and one time during 1998, 1999 and 2000, respectively, out of four possible sampling events per year. By definition, pore water samples are only analyzed for soluble constituents. As with the surface water quality data, 1999 had the greatest number of successful sample collection and the highest measured TDP and SRP mean concentrations when compared to the other pre-discharge years. The yearly mean TDP concentrations across all sites were 0.016, 0.095, and 0.055 mg/L for 1998, 1999, and 2000, respectively. The yearly mean SRP concentration values were 0.006, 0.067, and 0.030 mg/L, respectively (**Table 2**). Due to the limited number of samples collected, it was impossible to discern any spatial trend in any P parameters during the pre-discharge period, with the high outlier values occurring in 1999 following the muck fire (**Fig. 5**). **Table 2** provides the overall and yearly means for the other analyzed parameters, while a complete table of means, standard deviations, minimum and maximum values can be found in **Appendix IIA**. Additionally, box plots

displaying the yearly mean concentration values for all measured parameters are presented in **Appendix IIB**.

### Soil Properties

The mean soil bulk densities (Bd) and mean TP concentrations for the 0-2 cm section were 0.400 mg/cm<sup>3</sup> and 637 mg/kg, respectively (**Table 4**). These 0-2 cm section values were significantly higher ( $p < 0.001$ ) than their respective concentrations at the 2-10 cm and 10-20 cm depths (**Fig. 6**). However, this trend was not readily apparent in the percent ash content, TC and TN concentrations (**Fig. 7**).

### Periphyton

Deployment of the periphytometers was intermittent during the pre-discharge period due to the lack of standing water in the RWMA during this time. Periphytometers were successfully deployed at the sites all sites during 1999 and 2000, but chlorophyll *a* samples were lost during processing in 1999. Therefore, due to the limited number of data points, chlorophyll *a*, biomass, and nutrient concentration values are not presented in this report. A total of 187 species were identified during the pre-discharge period, and the complete list can be found in **Appendix III-A**. Preliminary analysis indicated that the 1999 taxa may have been highly affected by the muck fire and were extremely dissimilar to the taxa collected in 2000, in which only 23 different species were collected.

### Macrophytes

Data from the macrophyte surveys collected during the pre-drainage period indicate that while sawgrass and cattail (obligate wetland species) are widespread, the overall vegetation composition was indicative of a system transitioning to an upland habitat. Grass species, such as *Panicum spp.* (facultative wetland) and *Andropogon spp.* (facultative wetland and facultative), that can tolerate short-term flooded conditions, but prefer moist to drained soils, were prevalent. In addition several facultative species such as *Eupatorium capillifolium*, *Senecio glabellus*, *Teucrium canadense*, and *Erigeron quercifolius* were numerous in count and are typically found in disturbed and drained conditions.

The vegetation biomass and nutrient concentration data was extremely variable. Therefore, no significant difference was found spatially (i.e., along each transect line) or temporally (i.e., seasonally or yearly) within the two major species groups (cattail and sawgrass). Therefore, for this report, the pre-discharge biomass data were pooled together by species. In general the cattail dominated plots had lower mean biomass values than the sawgrass dominated plots, with mean values for the live and dead leaves of 179.1 g/m<sup>2</sup> and 291.4 g/m<sup>2</sup> for the cattail and 408.3 g/m<sup>2</sup> and 481.5 g/m<sup>2</sup> for the sawgrass, respectively (**Table 5**), but the variance within the plots obscured any significant difference between the groups (**Fig. 8**). Total P concentration in live leaves of cattail was 674.0 mg/kg, which was greater than the 419.6 mg-P/kg measured within the sawgrass plots, while the TP concentration found within the rhizomes were similar (**Table 5**). Additionally, mean total nitrogen (TN) concentrations measured within live leaves and roots were similar for both cattails and sawgrass species. Dead leaves were not assayed for nutrient concentration.

### **Post-Discharge Period (July 2001-June 2003)**

There were no major fires or hurricanes in the RWMA during the post-discharge period.

#### Hydrology

Direct rainfall onto the RWMA was again the major source of water for the system and totaled 86.76 in, providing 209,670 ac-ft during the post-discharge period, but an additional 86,990 ac-ft were received in through the G-410 structures during this period (**Table 3**). The G-402 outflow structures were also operated during this period and discharged a total of 29,262 ac-ft. However, the G-402 structures were continuously open from July 2002 until December 2002, when 28,197 ac-ft was discharged, which was the bulk of the total flow discharged over the entire two-year period.

The measured surface water depth ranged between below ground level to a high of 1.31 ft during this period. The monthly mean stage level readings ranged from a low of 11.3 ft to a high of 13.4 ft (**Fig. 9**). While at times these values were below the NSM interim stage level targets set for the RWMA hydropattern restoration efforts, there were several periods where the stage was at or close to the target levels. Mean stage values

ranged from 0.1 to 0.7 ft below the target, indicating that the system was trending toward hydropattern restoration. However, the NSM model assumed a floor of 12.3 ft, which is 0.25 ft above the mean ground elevation (12.05 ft) for the RWMA, while the stage gauges were designed to measure water levels below ground level, resulting in values less than 12.3 ft during the dry season. Additionally, from about July 2002 to December 2002 the RWMA G-402 outflow structures were operated in accordance with the RWMA operation manual, which indicates that these structures should be open when internal stage levels attain 12.3 ft. This resulted in 14,241 cfs being discharged from the system during this period and, in addition to natural factors, such as below average rainfall, evapotranspiration rates, and seepage, was a contributing factor in not attaining the NSM interim stage targets.

### Surface Water

During the entire post-discharge period, the mean outflow TP concentration through the G-402 structures was less than mean inflow TP concentration into the RWMA through the G-410 structure, with flow-weighted means of 0.033 mg/L and 0.083 mg/L, respectively (**Table 3**). Outflow from the G-402 structures during this period was intermittent and infrequent, with fewer gate openings occurring during the first year of the post-discharge period.

Surface water was collected from the RWMA six, eight, and two times for 2001, 2002 and until June 2003, respectively. The mean surface water TP concentration value for entire post-discharge period was 0.034 mg/L (**Table 6**). However, the mean TP concentration values at the 0.25 km stations was 0.058 mg/L, which was significantly ( $p < 0.001$ ) elevated in comparison to the sites situated farther from the inflow (**Fig. 10**). This trend was even more apparent with mean TDP and SRP concentration, where the mean concentration value at 0.25 km point was 0.035 mg/L, and 0.024 mg/L, respectively. This trend was different from the spatial trend exhibited by dissolved sulfate (DSO<sub>4</sub>), dissolved potassium (DK), dissolved chloride (DCI), dissolved magnesium (DMg), and dissolved sodium (DNa), where the mean concentration values trended toward lower values as distance from the inflow point increased (**Fig. 11**). A complete table of yearly means, standard deviations, minimum and maximum values can be found

in **Appendix IVA**. Box plots displaying the mean spatial concentration values for all measured parameters are presented in the **Appendix IVB** and the corresponding table with the descriptive statistics is found in **Appendix IVC**.

#### Porewater

Pore water was collected from the RWMA twice in 2001, three collections in 2002 and once in 2003 during the post-discharge period. **Table 7** provides the overall mean concentrations for all parameters analyzed for the porewater collected from the RWMA in the post-discharge period. Unlike the trend found regarding P surface water concentrations, the TDP and SRP porewater concentrations were elevated at the 0.5 km sample site with respect to the other sites (**Fig. 12**). A complete table of means, standard deviations, minimum and maximum values can be found in **Appendix VA**. Box plots displaying the spatial concentration values for all measured parameters are presented in **Appendix VB** and the corresponding table with the descriptive statistics is found in **Appendix VC**.

#### Soil Properties

Mean bulk densities were not significantly different among sites, years, or sections during the post-discharge period with mean values of 0.338, 0.314, and 0.399 mg/cm<sup>3</sup> for the 0-2, 10-20, and 10-20 cm sections, respectively (**Table 4** and **Fig. 13**). The percent ash content of the sediment displayed similar trends and the overall mean was 51% for all layers. In contrast, mean soil TP concentrations decreased with increasing depth (**Fig. 14**), with mean values of 655, 353, and 156 mg/kg at depths 0-2, 2-10, and 10-20 cm, respectively. However, TN and TC did not exhibit the same decreasing trend, but the deepest section (10-20 cm) had the lowest mean concentration values for both parameters.

#### Periphyton

Successful deployment of periphytometers occurred during the late wet season at sites N.25, N.5, N1, N2, N4 and S.5, S1, S2, S4 during 2001, N.25, N.5, N1, N2, N4 and S.25, S.5, S1, S2 during 2002, and all sites during 2003. Therefore, due to the limited

number of data points, chlorophyll *a*, biomass, and nutrient concentration values are not presented in this report. A total of 175 species were identified and **Appendix III-B** contains a complete species list. Preliminary analysis indicates that the taxa are representative of moderately enriched surface waters (TP concentrations between 20 and 30 µg/L) and enriched surface waters (TP>30 µg/L). Accordingly, taxa with higher relative abundances after STA-5 discharges began include 1) the cyanobacteria - *Anabaena* sp. and *Oscillatoria* sp., 2) diatoms, *Nitzschia* sp., and 3) chlorophyte - *Chlorella* sp.

### Macrophytes

Data from the post-discharge vegetation surveys indicated an initial response to the increased hydroperiod as evidenced by the presence of wetland obligate species such as cattail, sawgrass, *Utricularia foliosa*, *Sagittaria latifolia*, and *Pontederia cordata*. Cattail and sawgrass remained the dominate vegetation present, collectively representing about 70 to 75% of the RWMA. In addition, a mix of grasses (*Panicum* spp. and *Andropogon* spp.) and facultative wetland species (*Solidago* spp., *Teucrium canadensis* and *Senecio glabellus*) collectively made up about 25 to 30% of the remaining area. Additionally, *Utricularia foliosa* was recorded only during 2002 and, within the genus, is generally considered less sensitive to increased water column TP concentrations. We have noted an increase in the occurrence of *Salix caroliniana*, which is also associated with high soil nutrients.

Similar to the pre-discharge data, the post-discharge biomass data for the two major vegetation species (cattail and sawgrass) exhibited significant variation not only among sites but between sites, thus obscuring any evidence of spatial trends. Therefore, the data were pooled together by species then component into one representative number. Trends in dry biomass weight during the post-discharge period were similar to those noted during the pre-discharge period with mean biomass weights for dead and live sawgrass leave were significantly greater ( $p<0.05$ ) than the mean values measured in cattail vegetation leaves (**Fig. 15**). Additionally, mean biomass values for each measured sawgrass plot component had increased relative to the pre-discharge period, while means for each component within the cattail plots remained relatively unchanged (**Table 5**).

Mean TP concentrations measured in the roots and leaves were elevated relative to the pre-discharge period in both the sawgrass and cattail vegetation. However the trend for mean TP concentrations measured in both live leaves and roots mirrored that found during the pre-discharge period, with similar mean TP concentrations within the roots (1,039.5 and 1,340.0 mg/kg for cattail and sawgrass, respectively), but mean TP concentrations in the cattail live leaves greater than found in the sawgrass live leaves, with values of 933.2 and 506.2 mg/kg, respectively. Dead leaves were not assayed for nutrient concentration.

## Summary

Rainfall was the main source of water into the RWMA during the pre-discharge period. Data collected during this time supported that the RWMA was an impacted wetland trending toward an upland area and that changes in operation and management of this area were needed to ensure the protection of this area's natural resource value. The internal stage gauge readings indicated the system had no standing water much of the year, resulting in a shortened hydroperiod that promoted the growth of several facultative species indicative of drier habitats.

Post-discharge period data indicated a significant increase in hydroperiod, from 3 to 7 months, and was further supported in a doubling of the mean water depth from 0.4 ft during pre-discharge to 0.8 ft during the post-discharge period. While preliminary analysis indicated that in addition to natural factors, such as below average rainfall, evapotranspiration rates, and seepage, the opening of the G-402 outflow structures when stages reach 12.3 ft resulted in a decrease of water depth and was a contributing factor in not attaining the NSM interim stage targets, the comparison of the monthly mean stage levels during the pre- and post-discharge periods (**Figs. 2 and 9**), clearly shows the system was trending toward hydropattern restoration.

This increase in water hydroperiod and likely has a beneficial effect through decreasing the possibility of soil loss through muck fires. Furthermore, this increased hydroperiod period during the post-discharge period has resulted in the increase of obligate wetland species such as cattail (*Typha* spp.) and sawgrass. Cattail and sawgrass were the dominate vegetation present, collectively representing about 70 to 75% of the

RWMA, while a mix of grasses and facultative wetland species inhabited the remainder of the area

Preliminary analysis of the surface and pore water samples collected during the post-discharge period showed that phosphorus concentration levels may be elevated near the inflow relative to the outflow concentrations and continued monitoring is recommended to assess if this is a temporary and/or spatially stationary condition or indicative of a moving TP front. While an interim hydropattern restoration target has been set, it is not clear if these monthly targets will provide the optimum water levels, timing and duration that are needed to promote the desired ecosystem restoration. Therefore, we recommend continued monitoring of the vegetation and sediment within the RWMA along with the implementation of an adaptive management approach to continually assess if the NSM target is appropriate and the inflow source water of sufficient water quality so as to not negatively impact ecosystem restoration goals. A brief description of the monitoring program proposed for the RWMA can be found in **Appendix VI**. We also are investigating how to conduct small in-situ experiments that could be used to calculate the phosphorus storage in the upper 0-2 cm layer of the sediment in addition to quantifying the soil flux rates for soils exposed to STA discharge.

## **References**

- American Public Health Association, 1989. Standard Methods for the Examination of Water and Wastewater, Washington, DC.
- Smith, S.M., Z. Chen, J. Leeds, B. Garrett, J. Brewer, P. McCormick, and T. Fontaine. 1998. Baseline water quality, soil, periphyton, and macrophyte data from the Rotenberger Wildlife Management Area, 1998. Everglades System Research Division, Ecosystems Restoration Department, South Florida Water Management District, West Palm Beach, FL.
- Smith, S.M. J. Leeds, B. Garrett, and M. Darwish. 2000. Evaluation of rainwater retention in phased hydrologic restoration of the Rotenberger Wildlife Management Area, October 1999 – September 2000. Everglades Department, Watershed Research & Planning Division, South Florida Water Management District, West Palm Beach, FL.
- SFWMD, 2001. Operation Plan. Rotenberger Wildlife Management Area, June 2001, Environmental Engineering Section, Everglades Construction Project, South Florida Water Management District, West Palm Beach, FL.

SFWMD, 2004. Atlas of Flow Computation at District Hydraulic Structures, Technical Publication, Draft EMA Report, March 2004, Hydrology and Hydraulics Division, Environmental Monitoring and Assessment Department, South Florida Water Management District, West Palm Beach, FL.

USEPA, 1993. Methods for Chemical Analysis of Water and Wastes. Environmental Monitoring Support Laboratory, Cincinnati, OH.

**Table 1.** Units and annual means (July of one year through June of subsequent year) of surface water constituents collected monthly in the Rotenberger Wildlife Management Area during the pre-discharge period (From November 1997 through June 2001).

| Parameter                   | Units    | YEAR  |       |       |
|-----------------------------|----------|-------|-------|-------|
|                             |          | 1998  | 1999  | 2000  |
| Number of Sampling Events   | Months   | 2     | 6     | 2     |
| Temperature                 | °C       | 21.7  | 26.9  | 21.5  |
| Dissolved Oxygen            | mg/L     | 3.6   | 5.4   | 2.0   |
| Potential Hydrogen          | pH units | 7.0   | 7.8   | 7.2   |
| Specific Conductivity       | µhos/cm  | 181   | 283   | 321   |
| Soluble Reactive Phosphorus | mg/L     | 0.007 | 0.007 | 0.004 |
| Total Dissolved Phosphorus  | mg/L     | 0.011 | 0.030 | 0.018 |
| Total Phosphorus            | mg/L     | 0.018 | 0.085 | 0.033 |
| Total Dissolved Carbon      | mg/L     | 30.0  | 29.8  | 23.9  |
| Ammonium                    | mg/L     | 0.09  | 0.63  | 0.05  |
| Nitrate                     | mg/L     | 0.004 | 0.014 | 0.004 |
| Nitrate/Nitrite             | mg/L     | 0.008 | 0.014 | 0.009 |
| Total Dissolved Nitrogen    | mg/L     | 2.02  | 2.49  | 1.89  |
| Total Nitrogen              | mg/L     | 1.87  | 3.34  | 1.66  |
| Dissolved Sulfate           | mg/L     | 3.95  | 16.46 | 2.60  |
| Alkalinity                  | mg/L     | 126   | 131   | 153   |
| Dissolved Chloride          | mg/L     | 8.2   | 6.5   | 5.9   |
| Dissolved Calcium           | mg/L     | 50.1  | 54.2  | 61.1  |
| Dissolved Iron              | µg/L     | 285   | 227   | 313   |
| Dissolved Magnesium         | mg/L     | 3.9   | 4.8   | 4.8   |
| Dissolved Potassium         | mg/L     | 0.81  | 1.41  | 0.72  |
| Dissolved Sodium            | mg/L     | 4.8   | 4.8   | 4.4   |
| Dissolved Silica            | mg/L     | 4.02  | 3.39  | 3.49  |

**Table 2.** Units and annual means (July of one year through June of subsequent year) of pore water constituents collected quarterly in the Rotenberger Wildlife Management Area during the pre-discharge period (From November 1997 through June 2001).

| Parameter                   | Units    | YEAR  |       |       |
|-----------------------------|----------|-------|-------|-------|
|                             |          | 1998  | 1999  | 2000  |
| Number of Sampling Events   | Seasons  | 3     | 3     | 1     |
| Potential Hydrogen          | pH units | 7.3   | 7.5   | 7.4   |
| Soluble Reactive Phosphorus | mg/L     | 0.006 | 0.067 | 0.030 |
| Total Dissolved Phosphorus  | mg/L     | 0.016 | 0.095 | 0.055 |
| Total Dissolved Carbon      | mg/L     | 46.8  | 63.8  | 55.3  |
| Ammonium                    | mg/L     | 0.82  | 7.85  | 1.54  |
| Nitrate/Nitrite             | mg/L     | 0.463 | 0.988 | 0.335 |
| Total Dissolved Nitrogen    | mg/L     | 4.08  | 11.80 | 5.56  |
| Dissolved Sulfide           | mg/L     | 0.090 | 0.088 | 0.087 |
| Dissolved Sulfate           | mg/L     | 11.52 | 41.91 | 33.62 |
| Dissolved Chloride          | mg/L     | 9.8   | 14.7  | 8.9   |
| Dissolved Calcium           | mg/L     | 106.2 | 132.7 | 154.4 |
| Dissolved Iron              | µg/L     | 1286  | 1863  | 2779  |
| Dissolved Magnesium         | mg/L     | 7.4   | 9.4   | 10.0  |
| Dissolved Potassium         | mg/L     | 0.50  | 2.54  | 1.12  |

**Table 3.** Comparison of total rainfall, inflow through the G-410 pump and outflow through the four G-402 culverts during pre- and post-discharge periods for the Rotenberger Wildlife Management Area. The pre-discharge period represents 3.5 years and (November 1997 - June 2001), while the post-discharge period encompasses 2.0 years (July 2001 – June 2003).

| <b>Period</b>  | <b>Rainfall<br/>(ac-ft)</b> | <b>Inflow G-<br/>410 (ac-ft)</b> | <b>Water<br/>Quality G-<br/>410<br/>(mg/L)</b> | <b>Outflow G-<br/>402 (ac-ft)</b> | <b>Water<br/>Quality G-<br/>402<br/>(mg/L)</b> |
|--|-----------------------------|----------------------------------|--|-----------------------------------|--|
| Pre-discharge  | 390,751                     | 0                                | na   | 0                                 | na   |
| First year post-<br>discharge<br>(July 2001<br>through June<br>2002) |                             | 35,224 <sup>a</sup>              | 0.081 <sup>c</sup>                             | 1,015                             | 0.022 <sup>d</sup>                             |
| Second year<br>post-discharge<br>(July 2002<br>through June<br>2003) |                             | 51,766 <sup>b</sup>              | 0.085 <sup>c</sup>                             | 28,247                            | 0.035 <sup>d</sup>                             |
| Entire post-<br>discharge period                                     | 209,670                     | 86,990                           | 0.083  | 29,262                            | 0.033  |

<sup>a</sup> G-410 operated for 98 days during this period.

<sup>b</sup> G-410 operated for 176 days during this period.

<sup>c</sup> G-410 water quality concentrations are averaged flow-weighted means

<sup>d</sup> G-402 water quality concentrations are averaged flow-weighted means

**Table 4.** Units and overall means of measured parameters presented for soil cores collected annually in the Rotenberger Wildlife Management Area. Pre-discharge period extends from November 1997 through June 2001, and post-discharge period extends from July 2001 through June 2003. Soil samples sectioned into 0-2, 2-10, and 10-20 cm.

| Parameter        | Units              | Pre-Discharge Period  |         |         |
|------------------|--------------------|-----------------------|---------|---------|
|                  |                    | Soil Depth (cm)       |         |         |
|                  |                    | 0-2                   | 2-10    | 10-20   |
| Bulk Density     | mg/cm <sup>3</sup> | .400                  | .280    | .295    |
| Total Phosphorus | mg/kg              | 637                   | 351     | 176     |
| Total Nitrogen   | mg/kg              | 23,502                | 24,214  | 20,263  |
| Total Carbon     | mg/kg              | 311,113               | 335,756 | 296,911 |
| Ash Content      | %                  | 45.4                  | 41.6    | 50.1    |
|                  |                    | Post-Discharge Period |         |         |
|                  |                    | 0-2                   | 2-10    | 10-20   |
|                  |                    |                       |         |         |
| Bulk Density     | mg/cm <sup>3</sup> | .338                  | .314    | .399    |
| Total Phosphorus | mg/kg              | 655                   | 353     | 156     |
| Total Nitrogen   | mg/kg              | 24017                 | 22218   | 17702   |
| Total Carbon     | mg/kg              | 317666                | 310900  | 258738  |
| Ash Content      | %                  | 45.8                  | 48.8    | 57.6    |

**Table 5.** Comparison of biomass (dry weight) and nutrient concentrations (TP and TN) among cattail and sawgrass dominated plots located within the Rotenberger Wildlife Management Area. Pre-discharge period extended from November 1997 through June 2001 and post-discharge period was from July 2001 through June 2003. Dash represents values not assayed during these periods.

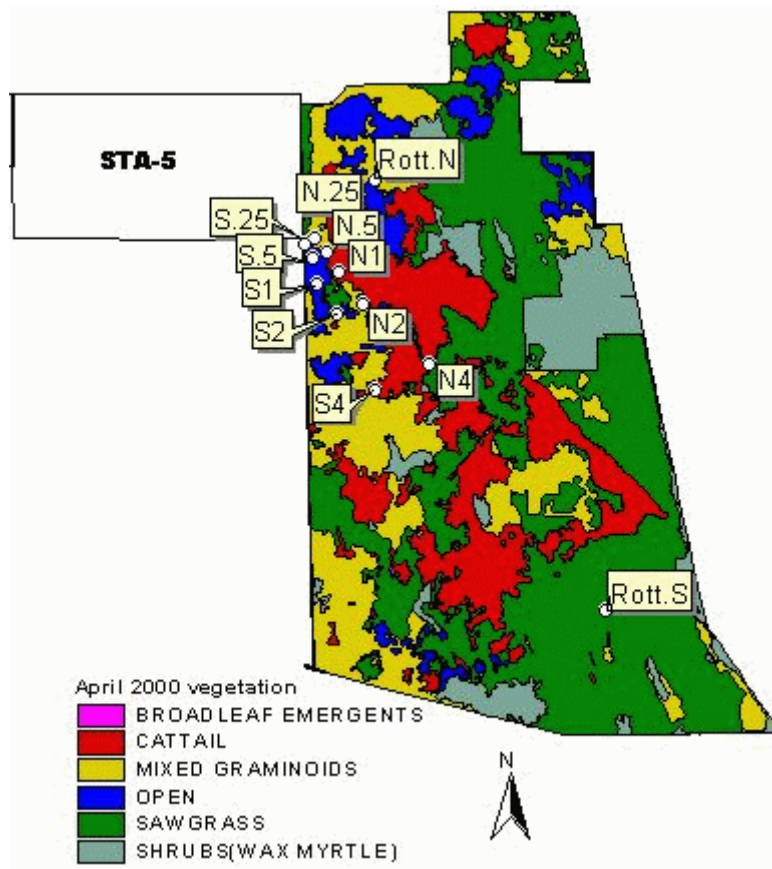
| <b>Vegetation/Component</b>                    | <b>Biomass (g/m<sup>2</sup>)</b> | <b>TP (mg/kg)</b> | <b>TN (mg/kg)</b> |
|--|----------------------------------|-------------------|-------------------|
| <b>Pre-discharge 0.25 m<sup>2</sup> plots</b>  |                                  |                   |                   |
| <b>Cattail/Dead leaves</b>                     | 291.4                            | -                 | -                 |
| <b>Cattail/Live leaves</b>                     | 179.1                            | 674.0             | 10,440.2          |
| <b>Cattail/Roots</b>                           | -                                | 357.8             | 7,130.7           |
| <b>Cattail/Other</b>                           | 484.5                            | -                 | -                 |
| <b>Sawgrass/Dead leaves</b>                    | 481.5                            | -                 | -                 |
| <b>Sawgrass/Live leaves</b>                    | 408.3                            | 419.6             | 11,054.8          |
| <b>Sawgrass/Roots</b>                          | -                                | 337.9             | 7,171.2           |
| <b>Sawgrass/Other</b>                          | 213.7                            | -                 | -                 |
| <b>Post-discharge 0.25 m<sup>2</sup> plots</b> |                                  |                   |                   |
| <b>Cattail/Dead leaves</b>                     | 246.8                            | -                 | -                 |
| <b>Cattail/Live leaves</b>                     | 216.1                            | 933.2             | 10,345.6          |
| <b>Cattail/Roots</b>                           | -                                | 1,039.5           | 7,060.1           |
| <b>Cattail/Other</b>                           | 481.2                            | -                 | -                 |
| <b>Sawgrass/Dead leaves</b>                    | 620.6                            | -                 | -                 |
| <b>Sawgrass/Live leaves</b>                    | 646.7                            | 506.2             | 9,770.6           |
| <b>Sawgrass/Roots</b>                          | -                                | 1,340.0           | 9,526.8           |
| <b>Sawgrass/Other</b>                          | 316.3                            | -                 | -                 |

**Table 6.** Units and bi-annual means (July of one year through June of subsequent year) of surface water constituents collected monthly in the Rotenberger Wildlife Management Area during the post-discharge period (From July 2001 through June 2003).

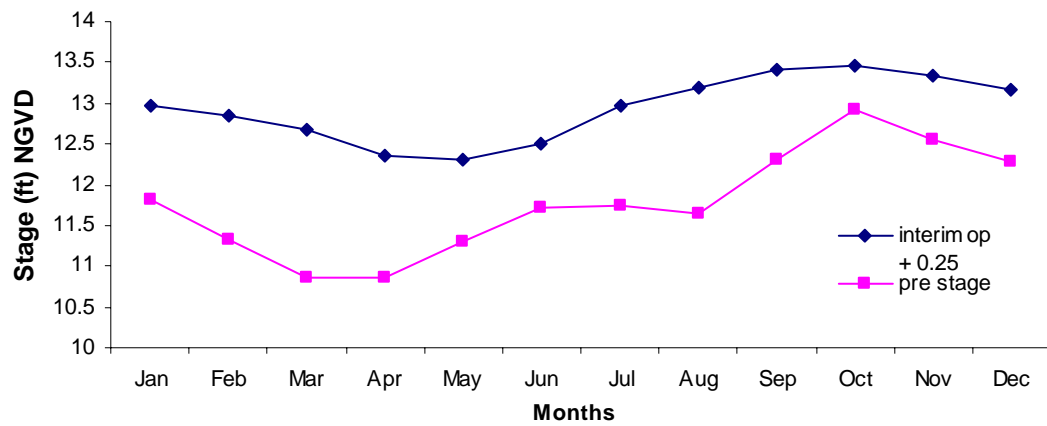
| Parameter                   | Units    | July 2001- June 2003 |
|-----------------------------|----------|----------------------|
| Number of Sampling Events   | Months   | 16                   |
| Temperature                 | °C       | 23.0                 |
| Dissolved Oxygen            | mg/L     | 2.2                  |
| Potential Hydrogen          | pH units | 7.2                  |
| Specific Conductivity       | µhos/cm  | 524                  |
| Soluble Reactive Phosphorus | mg/L     | 0.011                |
| Total Dissolved Phosphorus  | mg/L     | 0.017                |
| Total Phosphorus            | mg/L     | 0.034                |
| Total Dissolved Carbon      | mg/L     | 24.8                 |
| Ammonium                    | mg/L     | 0.04                 |
| Nitrate                     | mg/L     | 0.004                |
| Nitrate/Nitrite             | mg/L     | 0.007                |
| Total Dissolved Nitrogen    | mg/L     | 1.62                 |
| Total Nitrogen              | mg/L     | 1.66                 |
| Dissolved Sulfate           | mg/L     | 6.24                 |
| Alkalinity                  | mg/L     | 200                  |
| Dissolved Chloride          | mg/L     | 53.0                 |
| Dissolved Calcium           | mg/L     | 67.8                 |
| Dissolved Iron              | µg/L     | 251                  |
| Dissolved Magnesium         | mg/L     | 7.4                  |
| Dissolved Potassium         | mg/L     | 3.50                 |
| Dissolved Sodium            | mg/L     | 39.1                 |
| Dissolved Silica            | mg/L     | 4.28                 |

**Table 7.** Units and bi-annual means (July of one year through June of subsequent year) of pore water constituents collected monthly in the Rotenberger Wildlife Management Area during the post-discharge period (From July 2001 through June 2003).

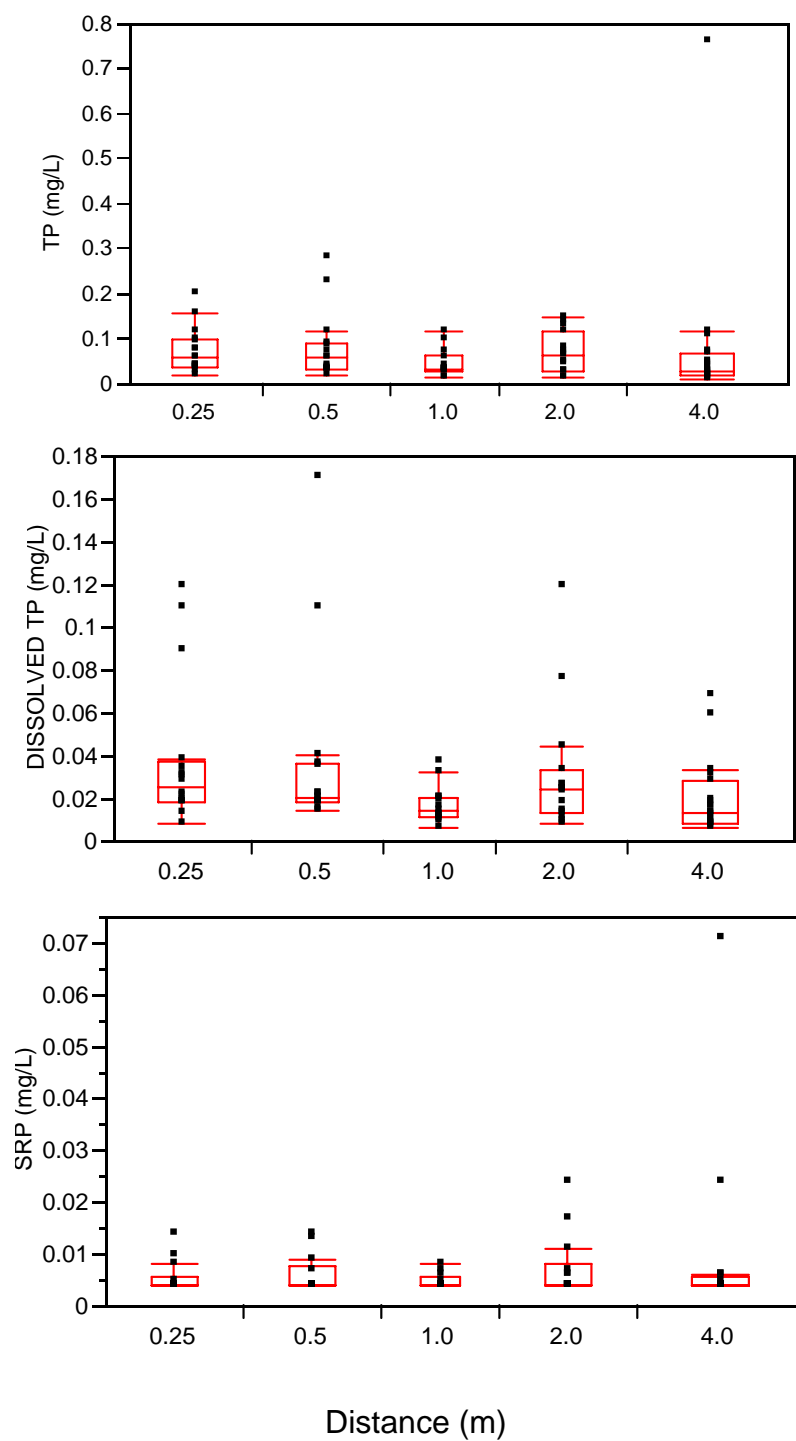
| Parameter                   | Units    | July 2001- June 2003 |
|-----------------------------|----------|----------------------|
| Number of Sampling Events   | Seasons  | 6                    |
| Potential Hydrogen          | pH units | 7.1                  |
| Soluble Reactive Phosphorus | mg/L     | 0.066                |
| Total Dissolved Phosphorus  | mg/L     | 0.101                |
| Total Dissolved Carbon      | mg/L     | 52.3                 |
| Ammonium                    | mg/L     | 2.12                 |
| Nitrate/Nitrite             | mg/L     | 0.313                |
| Total Dissolved Nitrogen    | mg/L     | 6.17                 |
| Dissolved Sulfide           | mg/L     | 0.097                |
| Dissolved Sulfate           | mg/L     | 8.52                 |
| Dissolved Chloride          | mg/L     | 51.1                 |
| Dissolved Calcium           | mg/L     | 172.4                |
| Dissolved Iron              | µg/L     | 3710                 |
| Dissolved Magnesium         | mg/L     | 12.3                 |
| Dissolved Potassium         | mg/L     | 1.84                 |



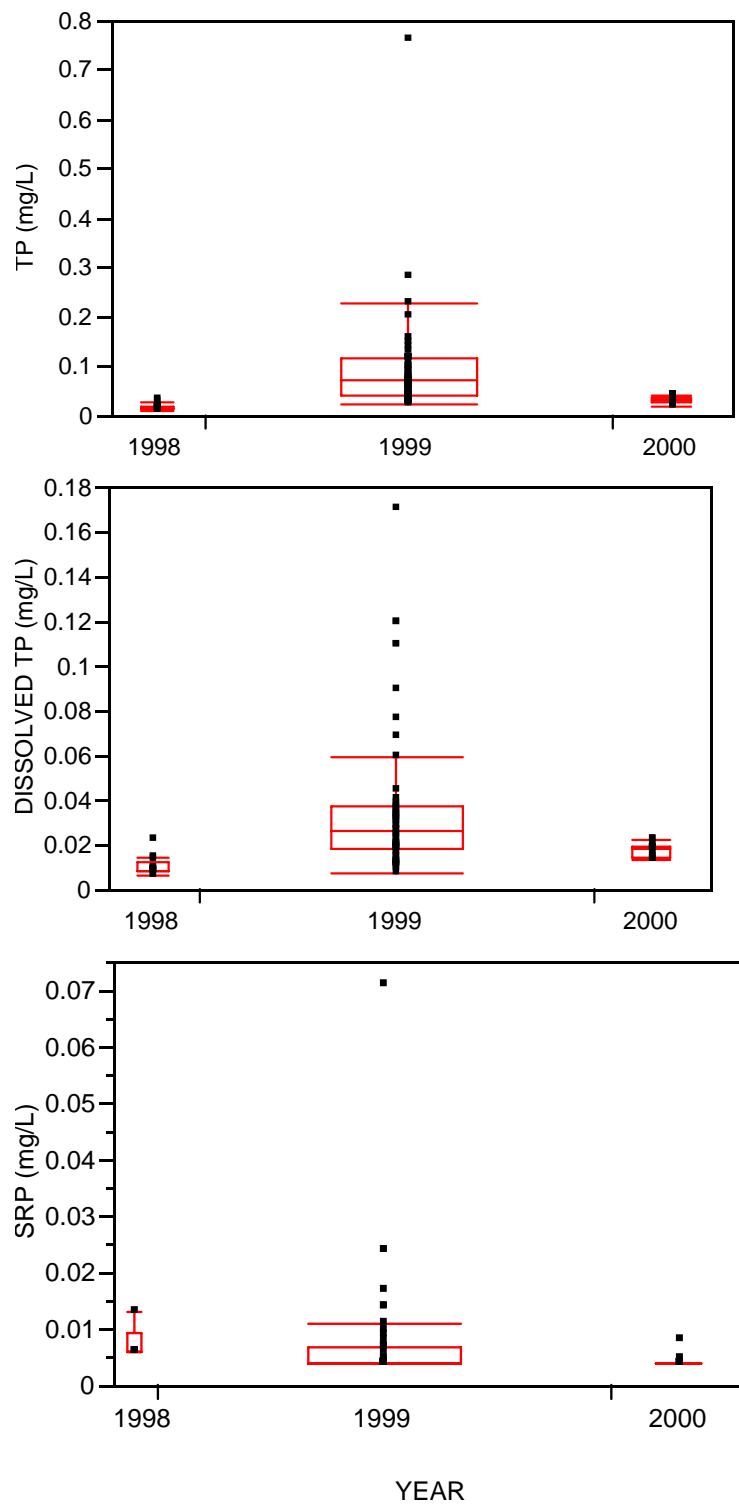
**Figure 1.** Map the Rotenberger Wildlife Management Area (RWMA) showing the distribution of the vegetation community dominate in 2000, the transects and stage gauge recorders during the period extending from November 1997 through June 2003.



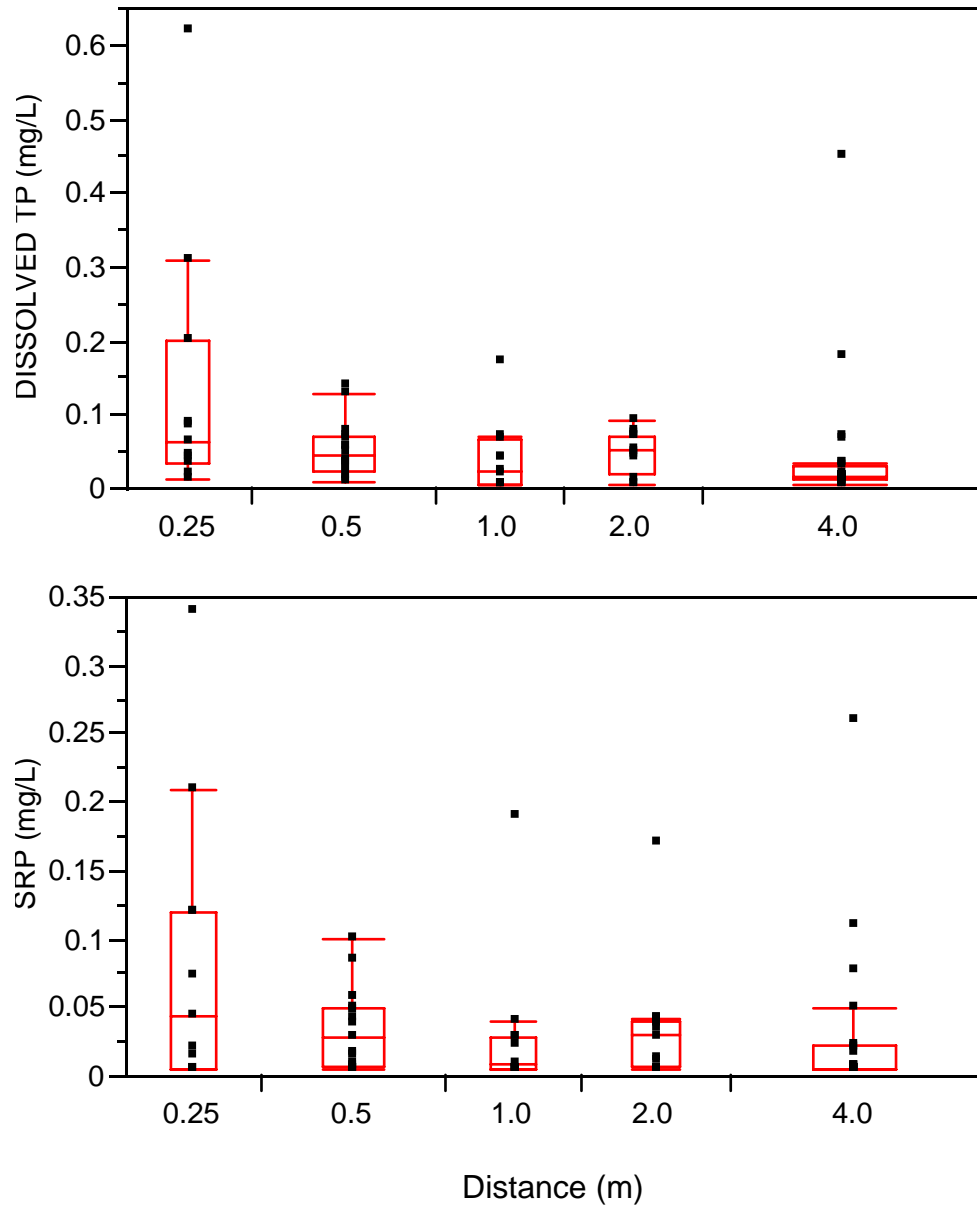
**Figure 2.** Monthly mean stage target elevations determined by the Natural Systems Model (NSM) are shown for the Rotenberger Wildlife Management Area (RWMA). Target stage includes a 0.25 ft offset. Also shown are the monthly mean stage levels recorded within the RWMA during the pre-discharge period, which extends from November 1997 through June 2001.



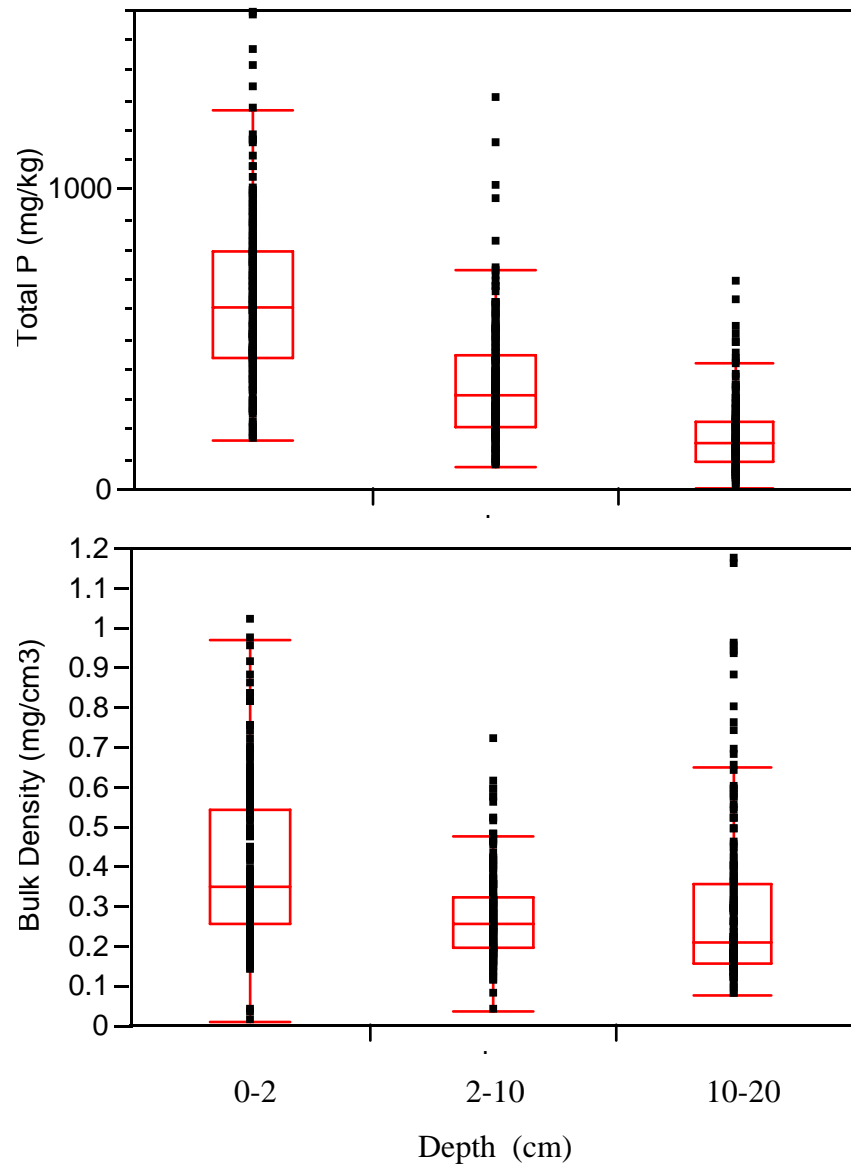
**Figure 3.** Box plots of mean monthly surface water TP, TDP and SRP concentrations for the pre-discharge period (November 1997 through June 2001) in the Rotenberger Wildlife Management Area.



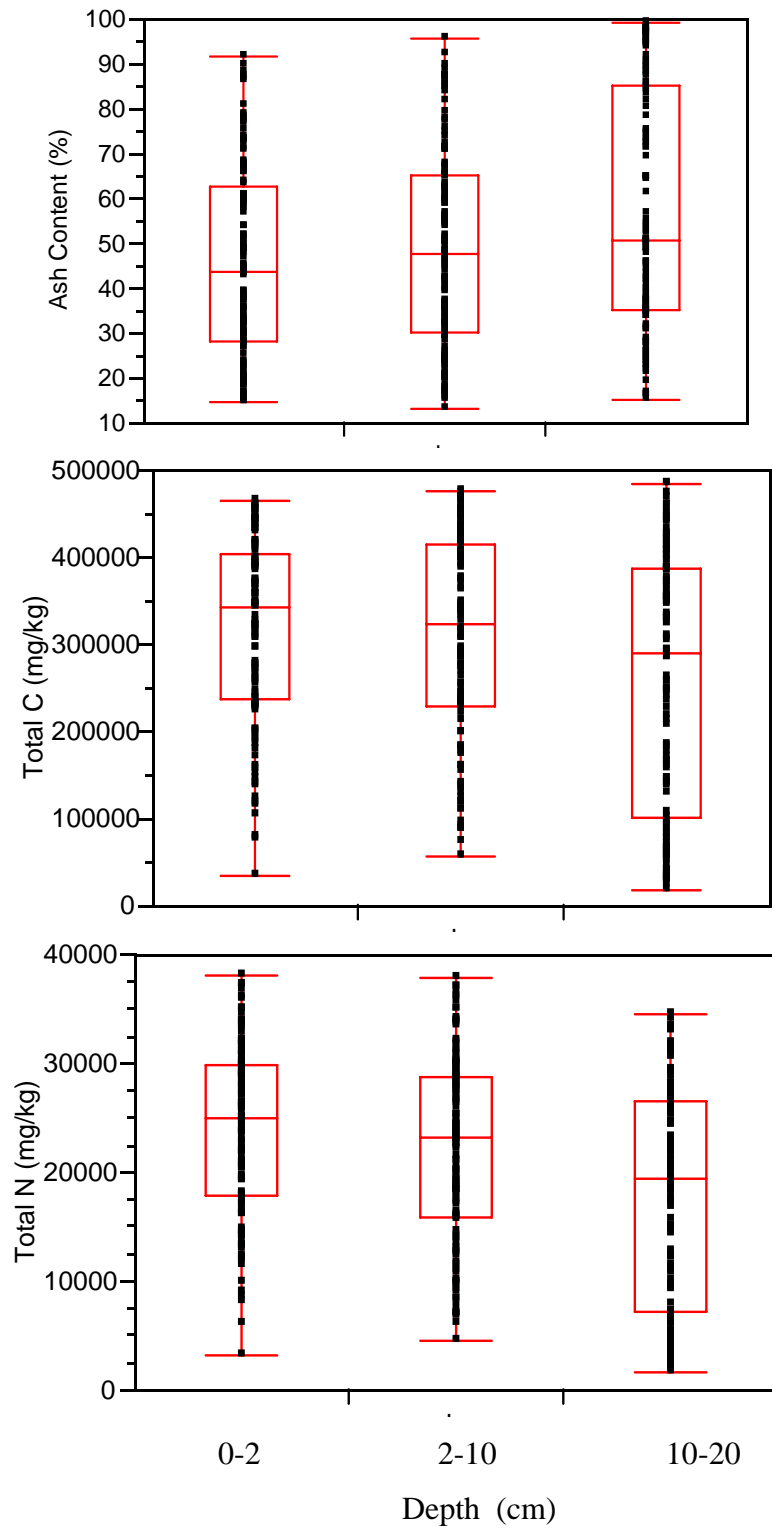
**Figure 4.** Box plots of yearly means for surface water P concentrations during the pre-discharge period (November 1997 through June 2001) in the Rotenberger Wildlife Management Area.



**Figure 5.** Box plots of mean monthly pore water TDP and SRP concentrations for the pre-discharge period (November 1997 through June 2001) in the Rotenberger Wildlife Management Area. Outlier concentration values were a result of the 1999 muck fires in the area.



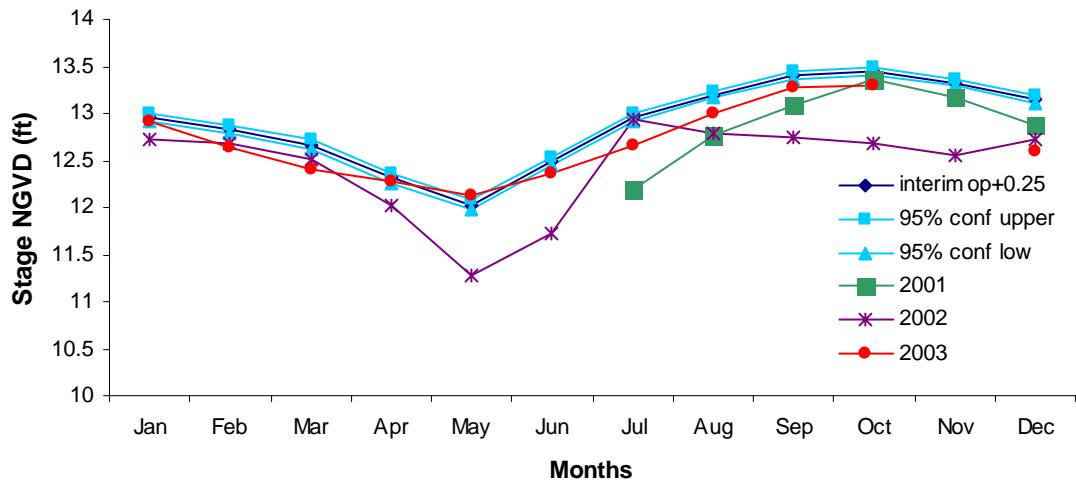
**Figure 6.** Comparison of mean bulk density and TP concentration values at various depths in the Rotenberger Wildlife Management Area. Samples taken during the pre-discharge period (November 1997 through June 2001).



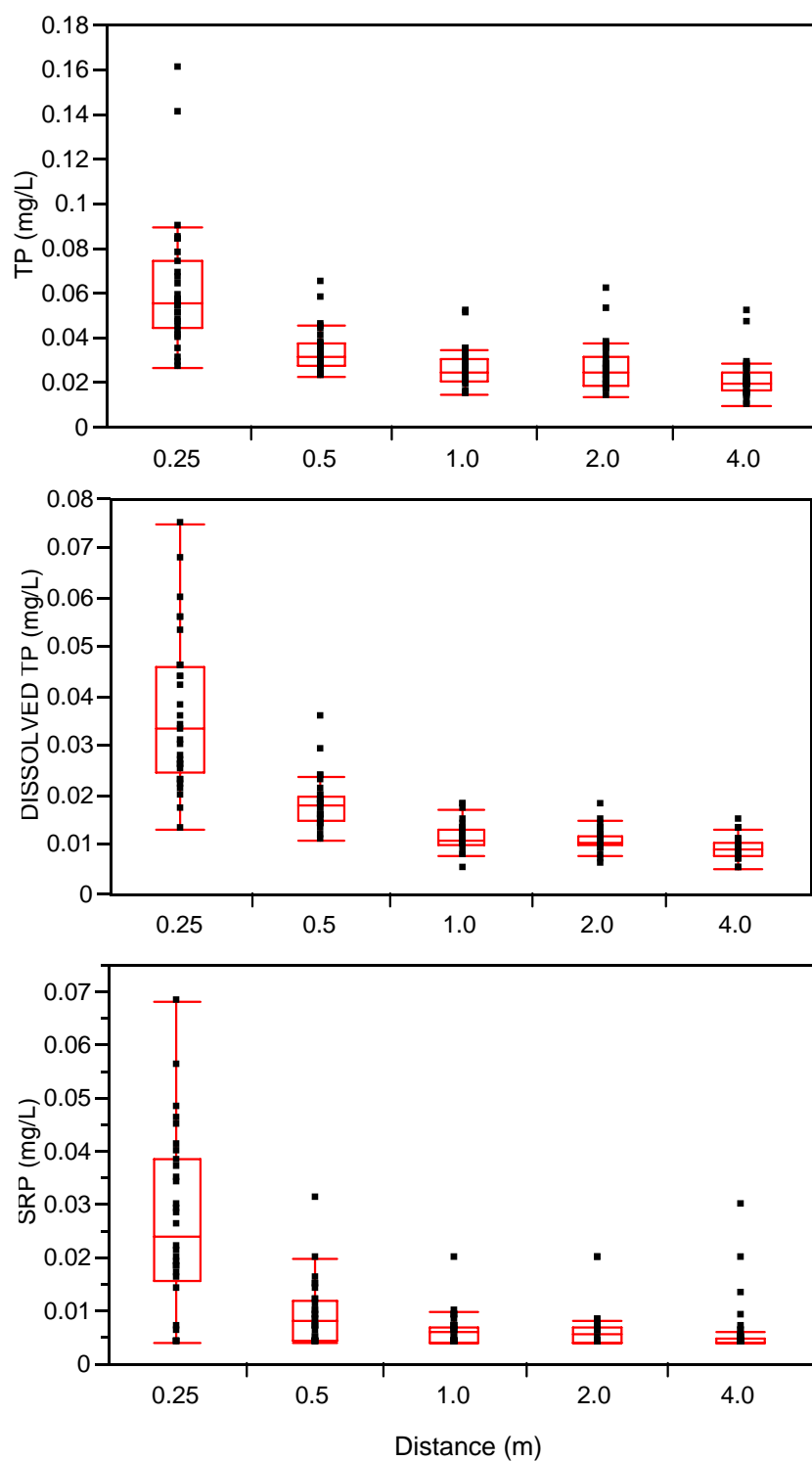
**Figure 7.** Comparison of percent ash, total carbon (TC) and total nitrogen (TN) soil concentrations at various depths in the Rotenberger Wildlife Management Area. Samples taken during the pre-discharge period (November 1997 through June 2001).



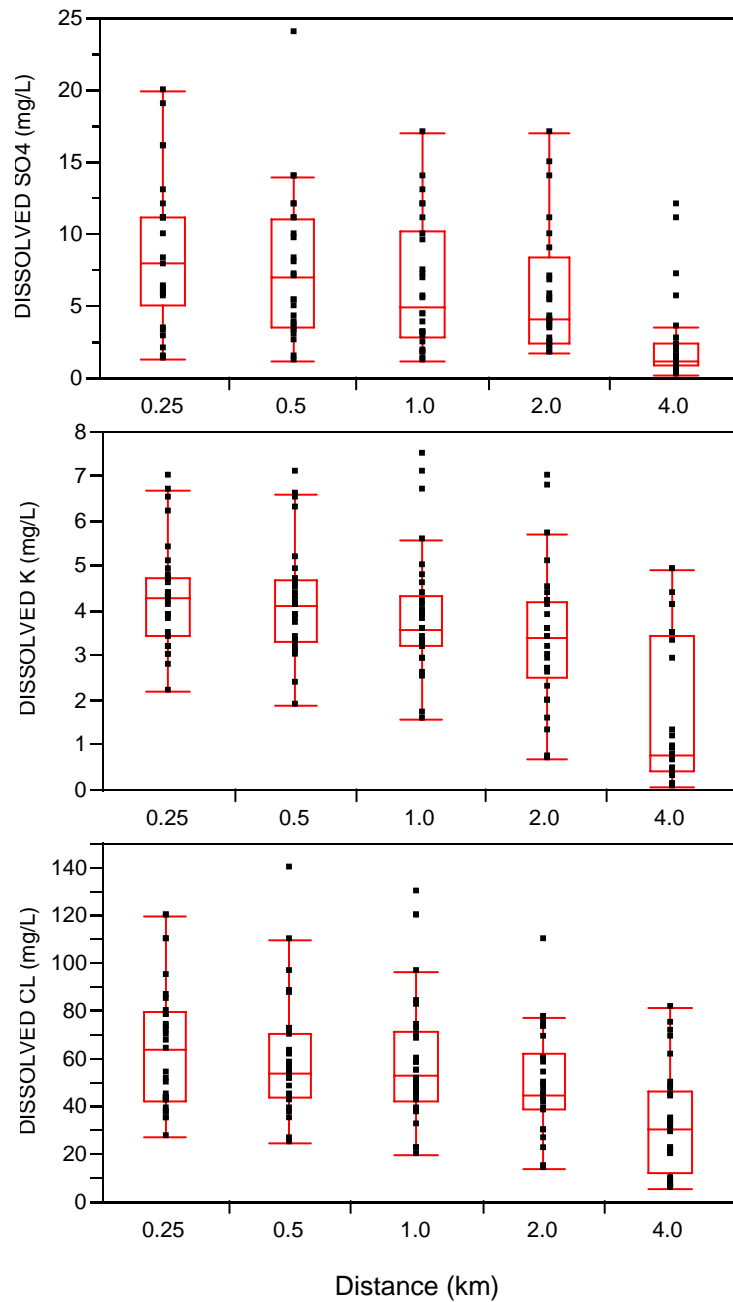
**Figure 8.** Comparison of cattail (Cat) and sawgrass (Saw) plant biomass (expressed as dry weight, g/m<sup>2</sup>) measured in 0.25 m<sup>2</sup> plots within the Rotenberger Wildlife Management Area during the pre-discharge period (November 1997 through June 2001). Cat/Dead = cattail dead leaves; Cat/live = cattail live leaves; Cat/other = other vegetation species within the cattail plots; Saw/dead = sawgrass dead leaves; Saw/live = sawgrass live leaves; Saw/other = other vegetation species within the sawgrass plots.



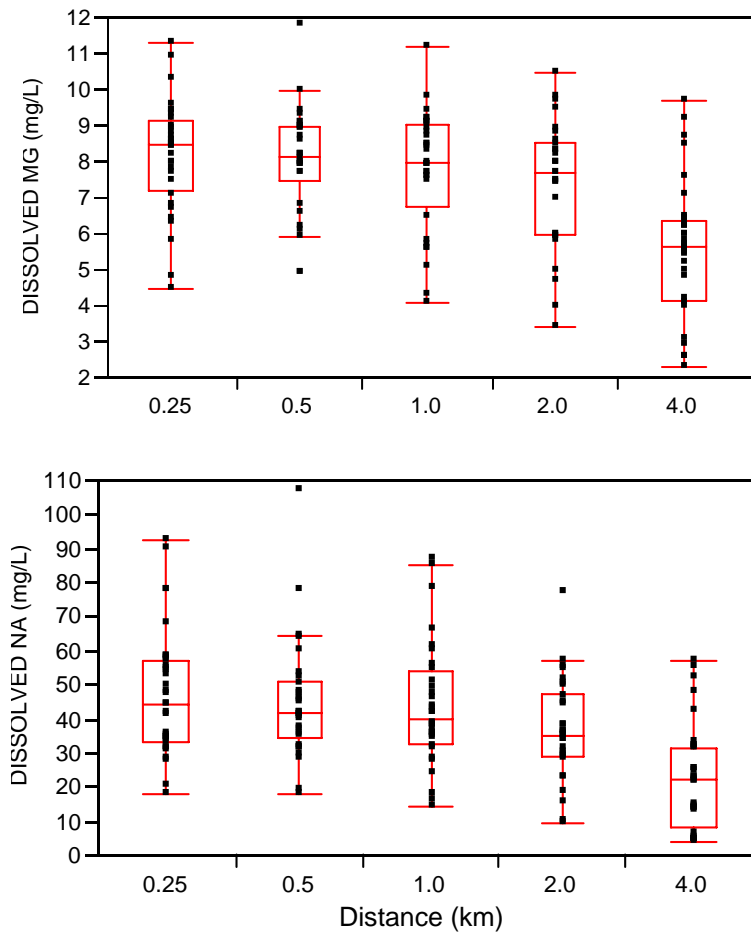
**Figure 9.** Monthly mean stage target elevations with 95% confidence intervals determined by the Natural Systems Mode (NSM) are shown for the Rotenberger Wildlife Management Area (RWMA). Target stage includes a 0.25 ft offset. Also shown are the monthly mean stage levels recorded within the RWMA during the post-discharge period, which extends from July 2001 through June 2003.



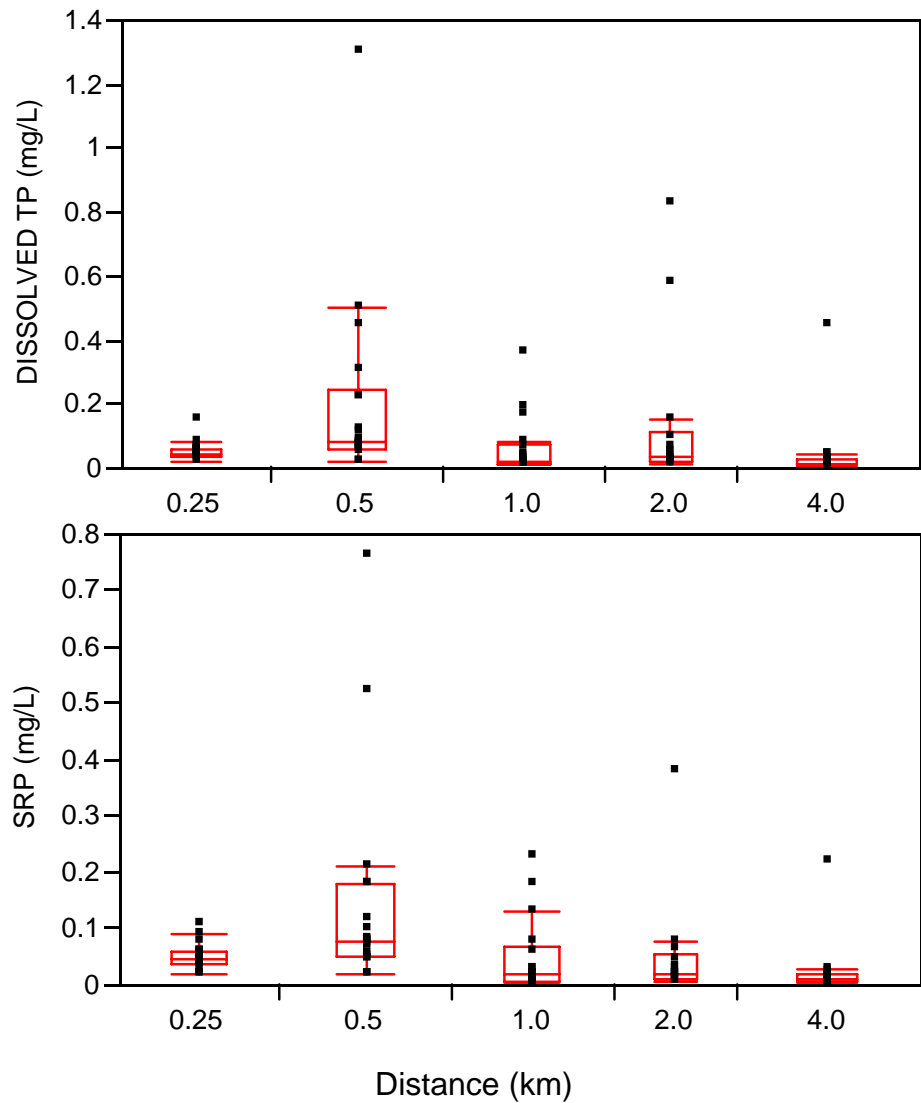
**Figure 10.** Box plots showing the spatial comparison of the surface water TP, TDP and SRP concentrations for the post-discharge period (July 2001 through June 2003) in the Rotenberger Wildlife Management Area.



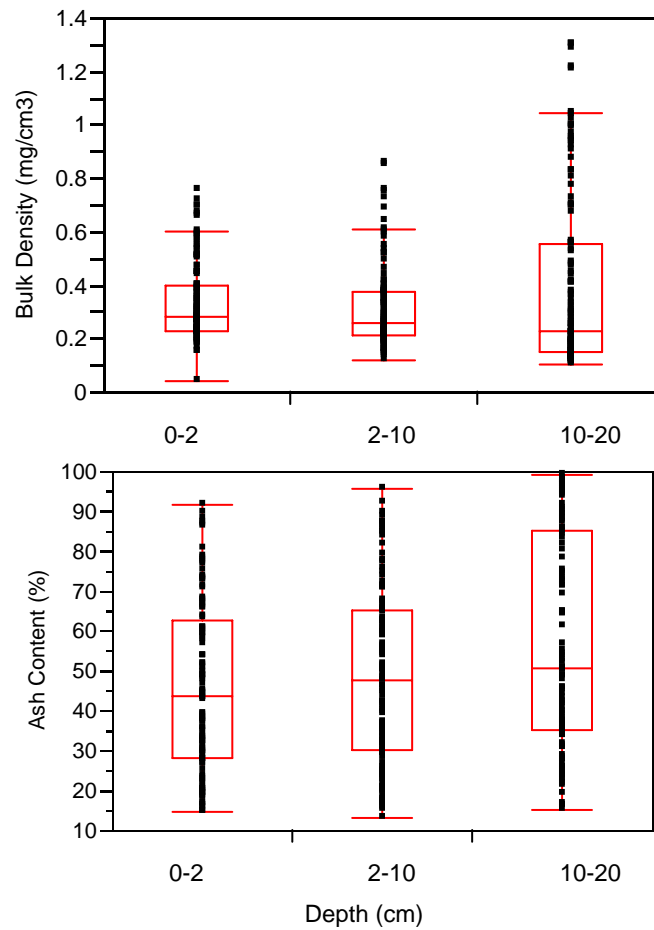
**Figure 11.** Box plots showing the spatial comparison of the surface water DSO<sub>4</sub>, DK, DCl, DMg, and DNa concentrations for the post-discharge period (July 2001 through June 2003) in the Rotenberger Wildlife Management Area.



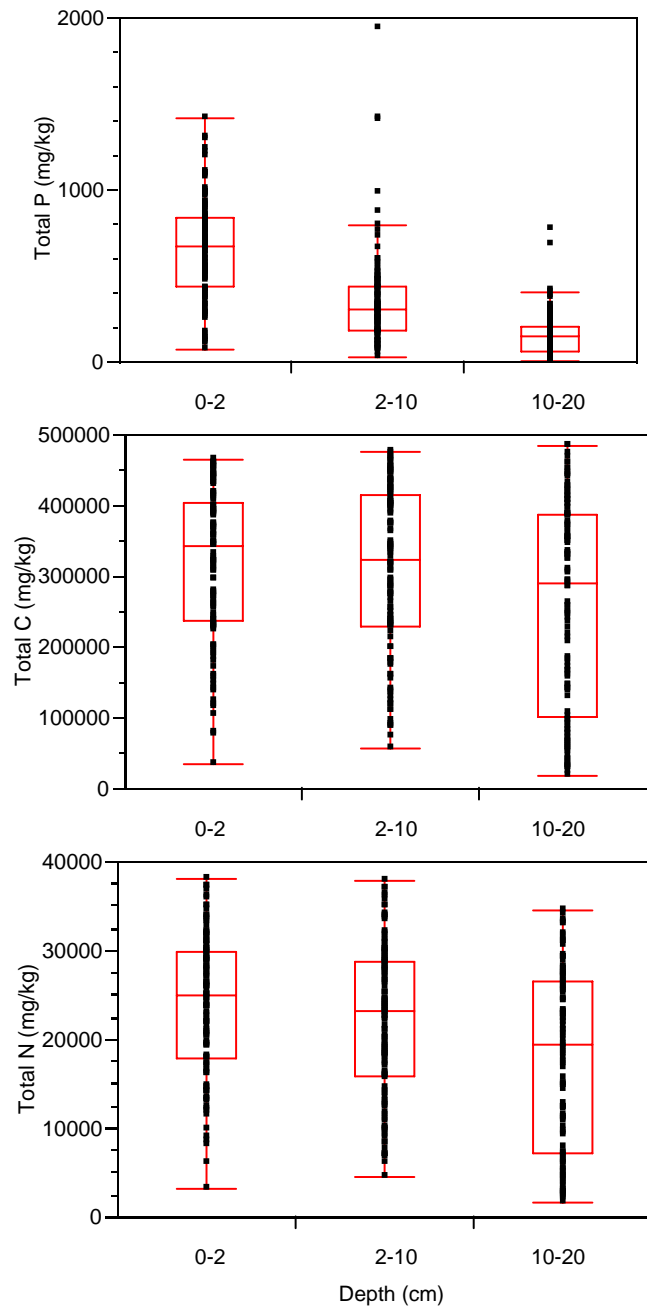
**Figure 11 continued.** Box plots showing the spatial comparison of the surface water DSO<sub>4</sub>, DK, DCl, DMg, and DNa concentrations for the post-discharge period (July 2001 through June 2003) in the Rotenberger Wildlife Management Area.



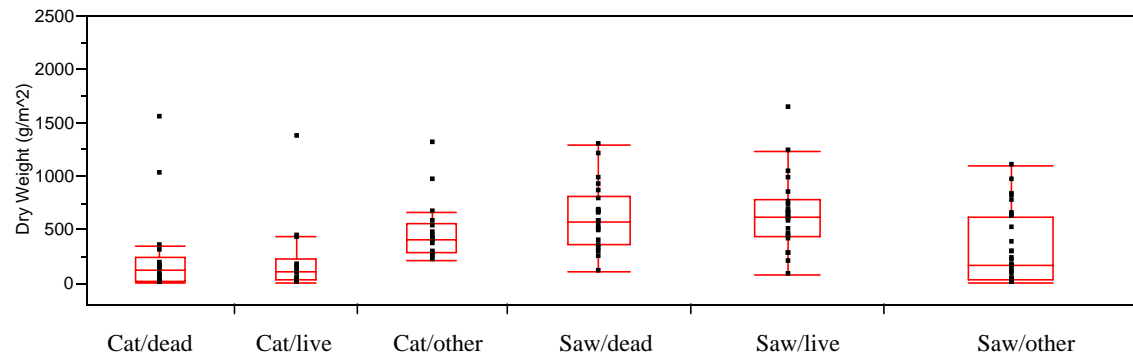
**Figure 12.** Box plots showing the spatial comparison of the pore water TDP and SRP concentrations for the post-discharge period (July 2001 through June 2003) in the Rotenberger Wildlife Management Area.



**Figure 13.** Comparison of mean bulk density and percent ash values at various depths in the Rotenberger Wildlife Management Area. Samples taken during the post-discharge period (July 2001 through June 2003).



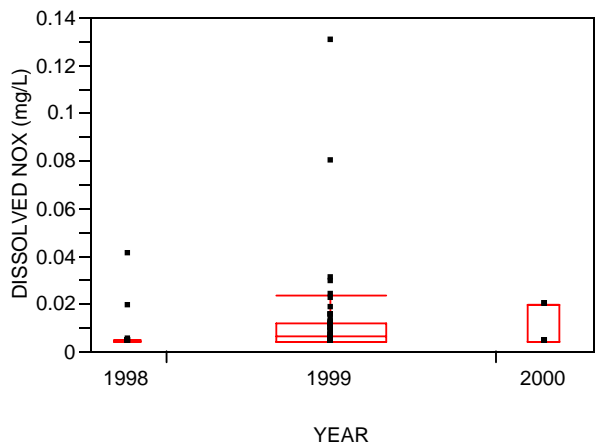
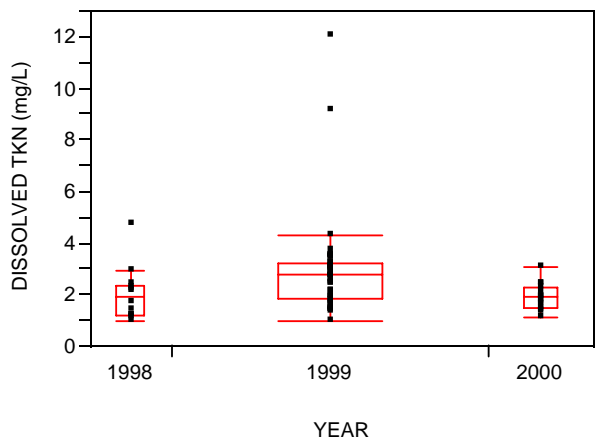
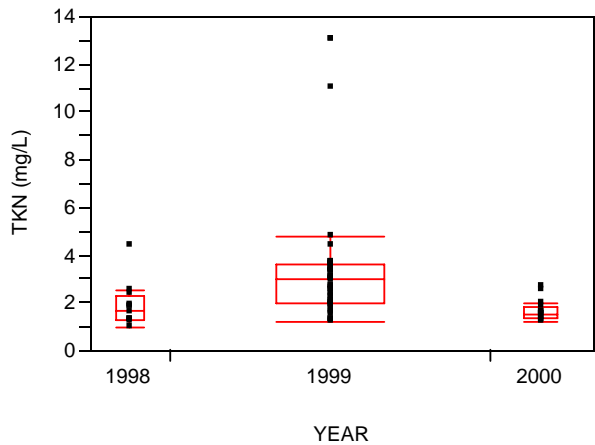
**Figure 14.** Comparison of TP, TC and TN soil concentrations at various depths in the Rotenberger Wildlife Management Area. Samples taken during the post-discharge period (July 2001 through June 2003).

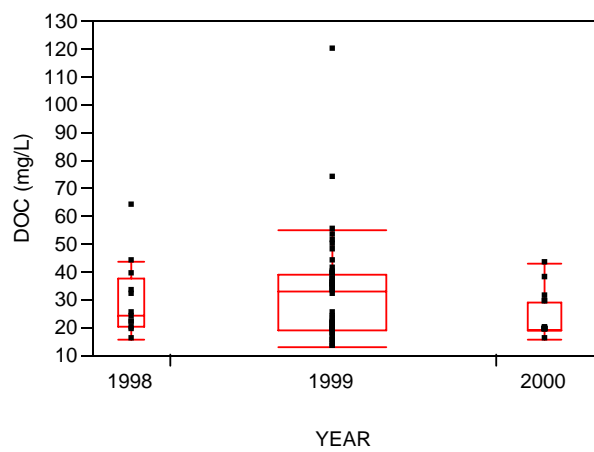
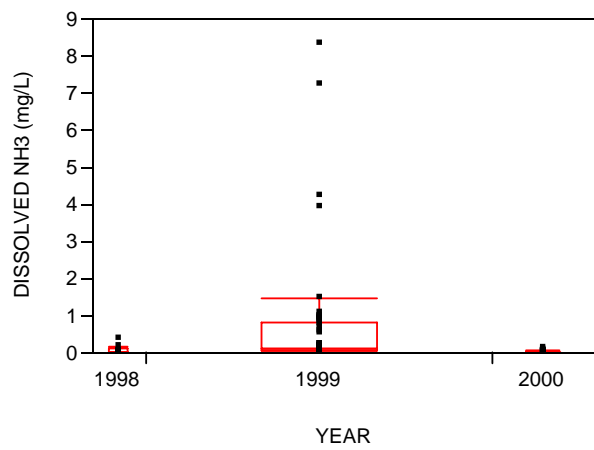
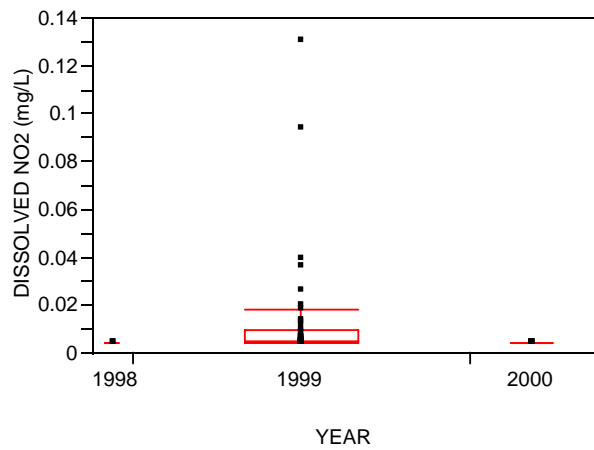


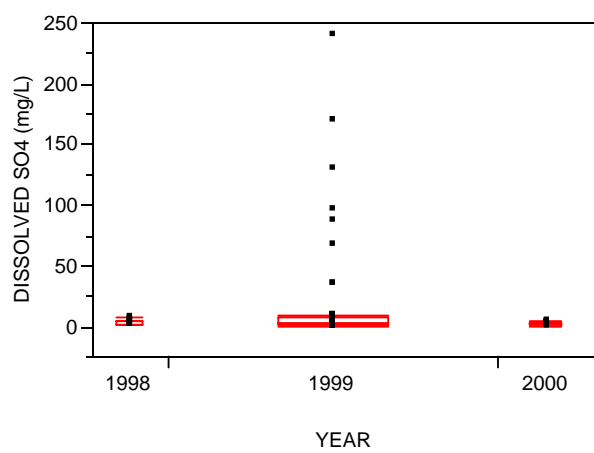
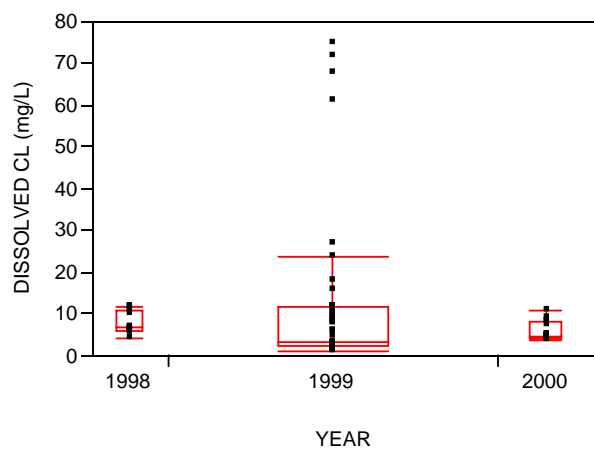
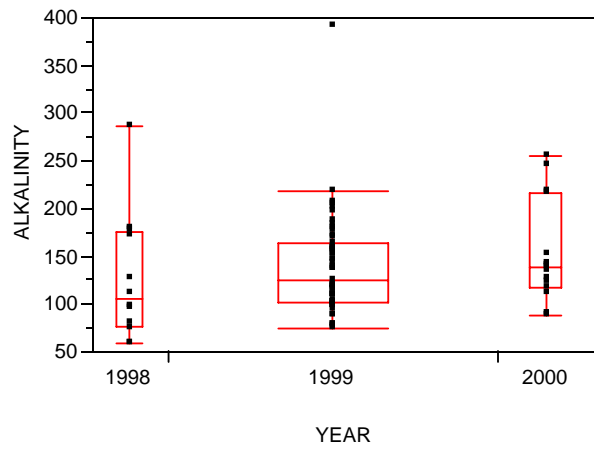
**Figure 15.** Comparison of cattail (Cat) and sawgrass (Saw) plant biomass (expressed as dry weight, g/m<sup>2</sup>) measured in 0.25 m<sup>2</sup> plots within the Rotenberger Wildlife Management Area during the post-discharge period (July 2001 through June 2003). Cat/Dead = cattail dead leaves; Cat/live = cattail live leaves; Cat/other = other vegetation species within the cattail plots; Saw/dead = sawgrass dead leaves; Saw/live = sawgrass live leaves; Saw/other = other vegetation species within the sawgrass plots.

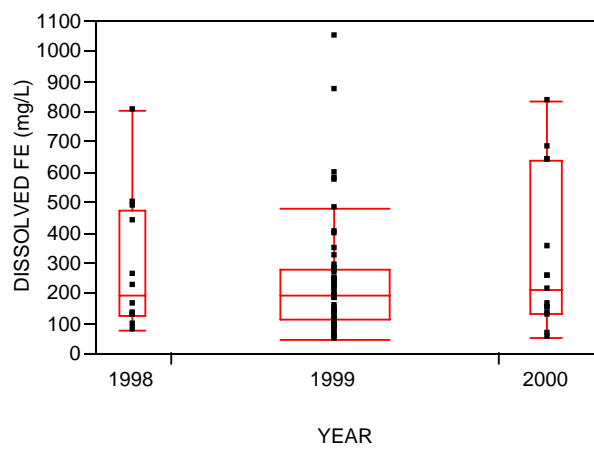
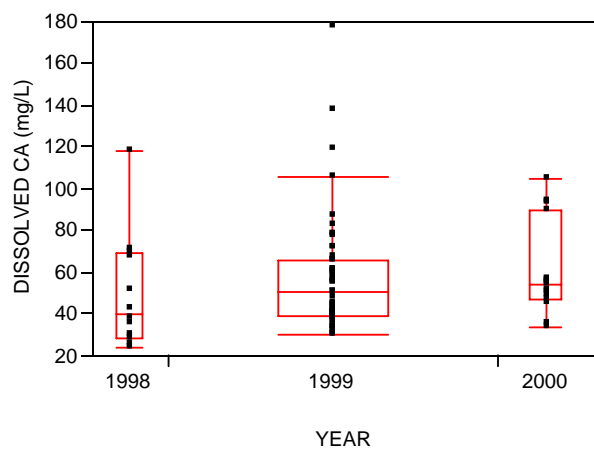
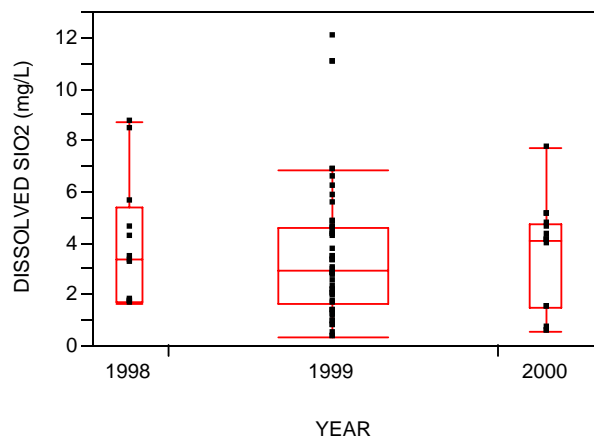
**APPENDIX IA.** INSERT TABLE HERE

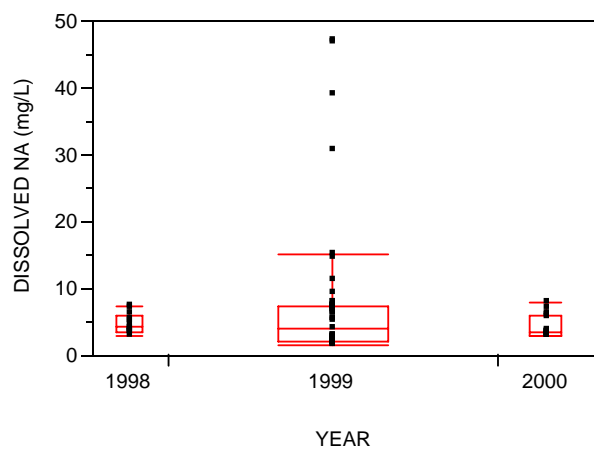
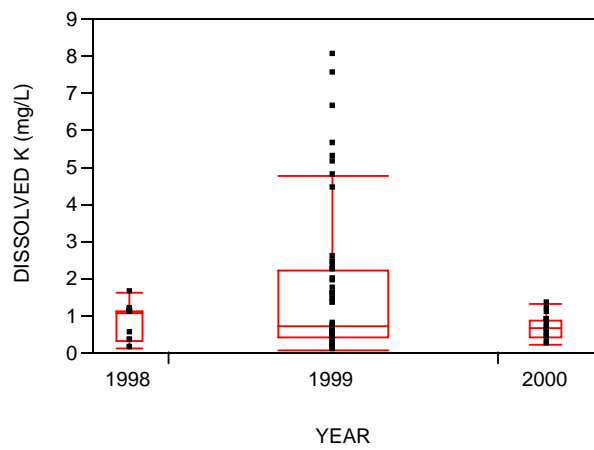
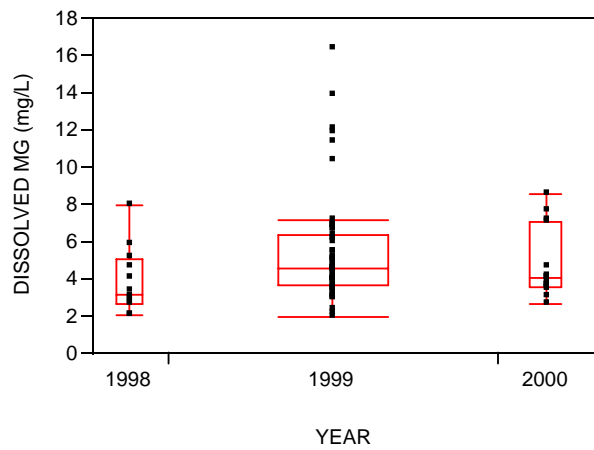
**APPENDIX IB.** Graphs comparing yearly mean surface water quality concentrations for the Rotenberger Wildlife Management Area during the pre-discharge period (November 1997 through June 2001). Appendix IB contains graphs of the following parameters: TKN, dissolved TKN, dissolved nitrate/nitrite, dissolved NO<sub>2</sub>, dissolved NH<sub>3</sub>, dissolved organic C, alkalinity, dissolved Cl, dissolved SO<sub>4</sub>, dissolved Si, dissolved Ca, dissolved Fe, dissolved Mg, dissolved K, dissolved Na, dissolved oxygen, temperature, specific conductance, and pH.

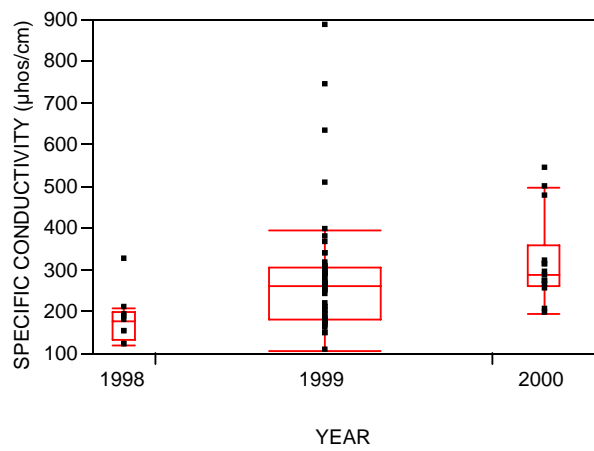
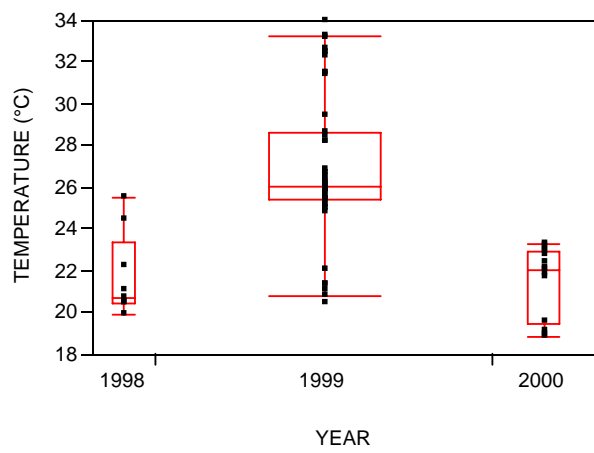
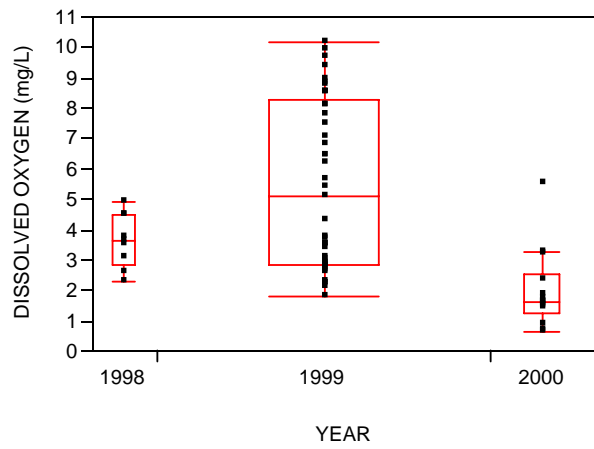


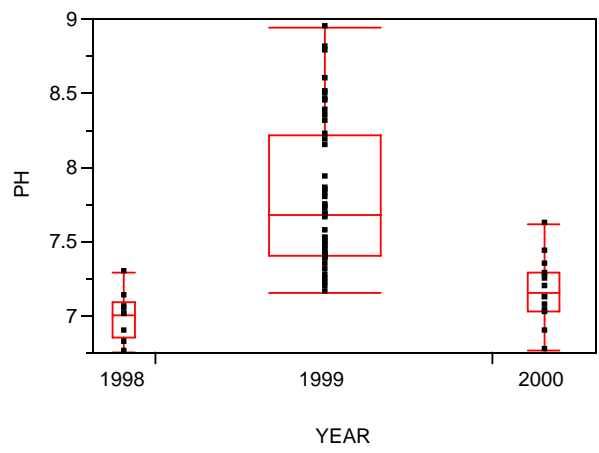






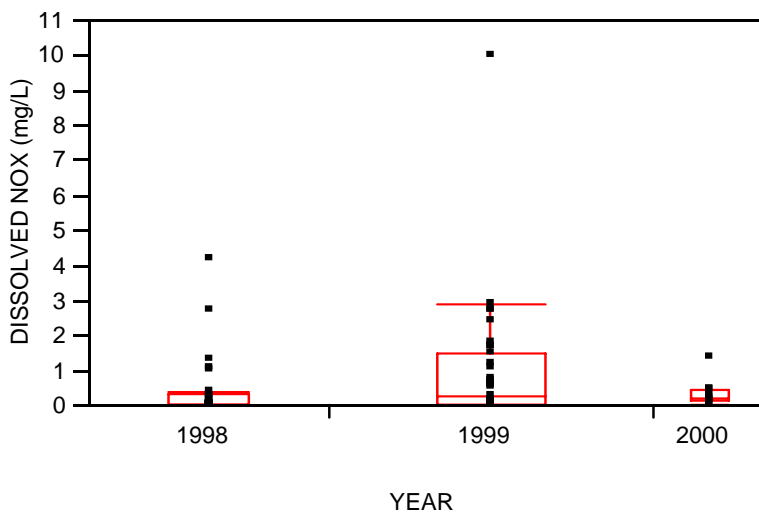
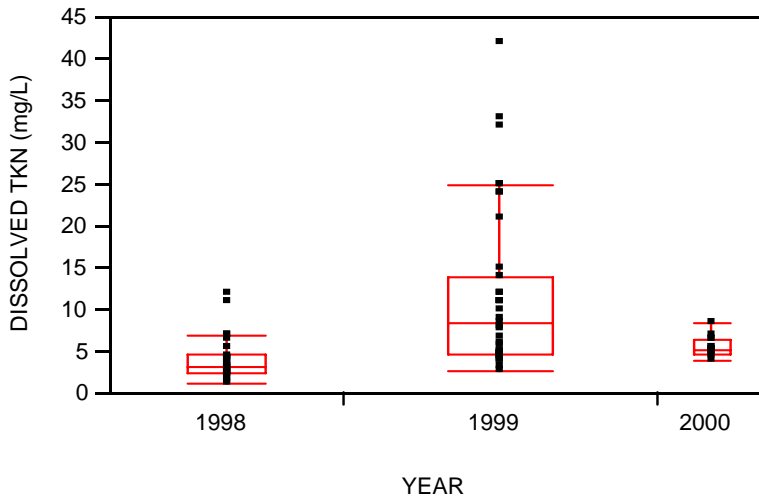


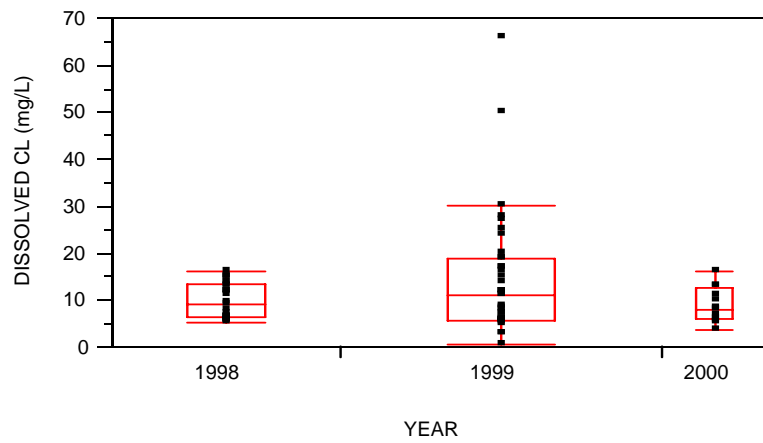
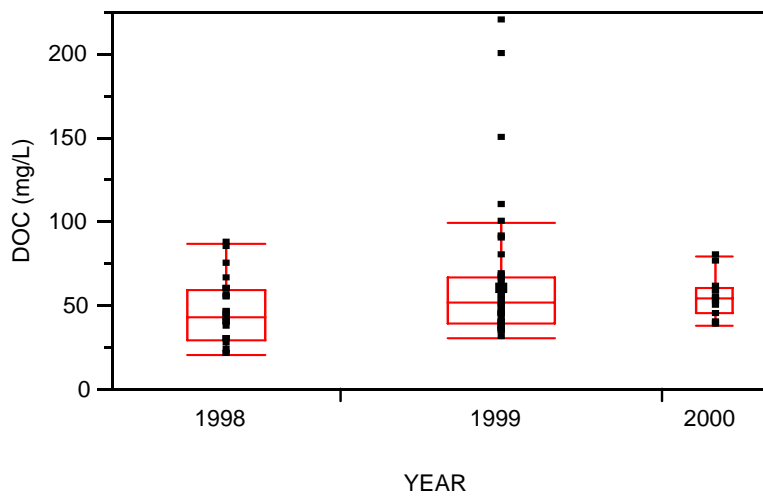
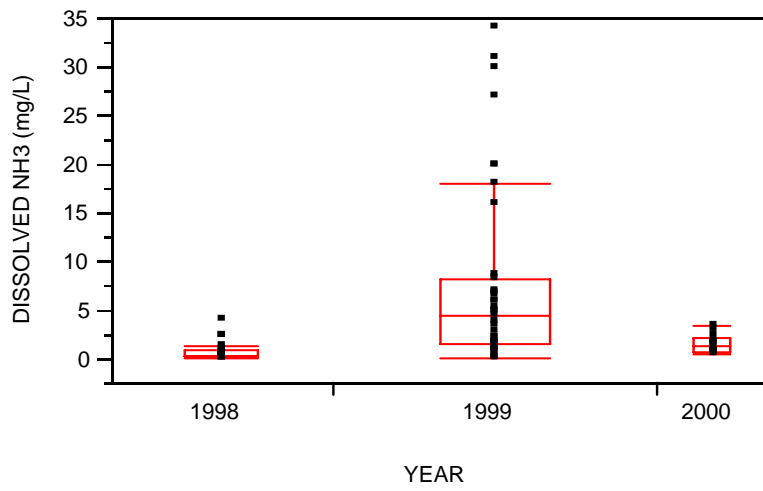


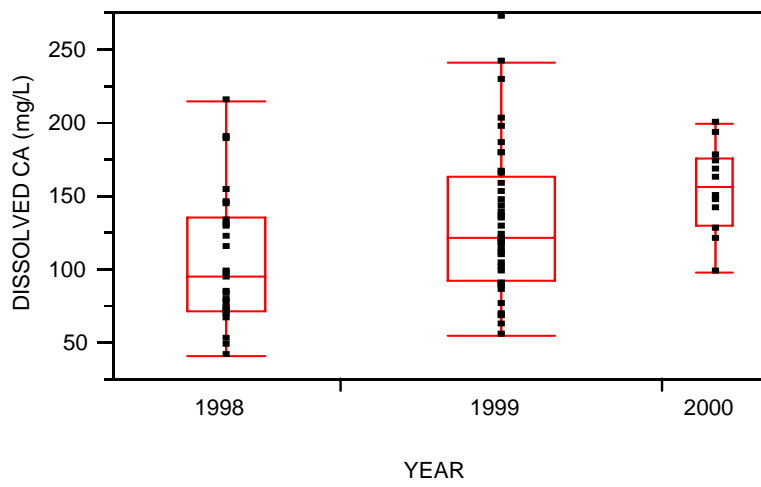
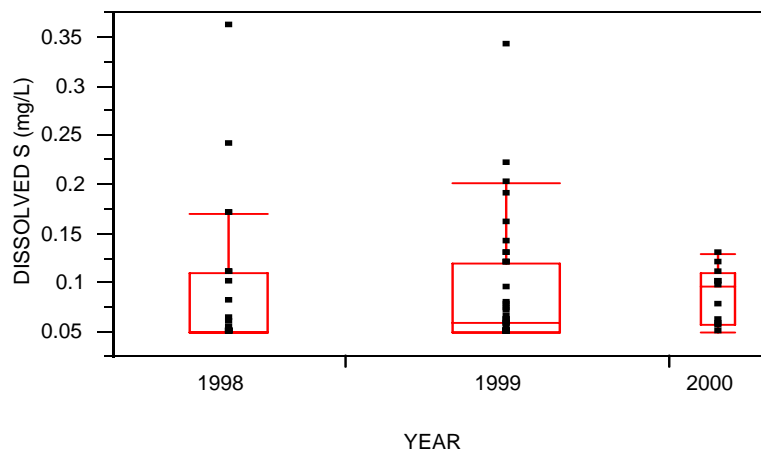
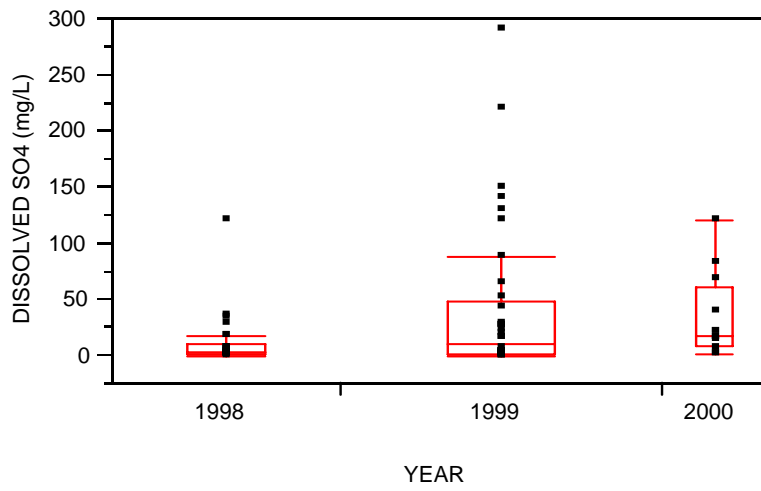


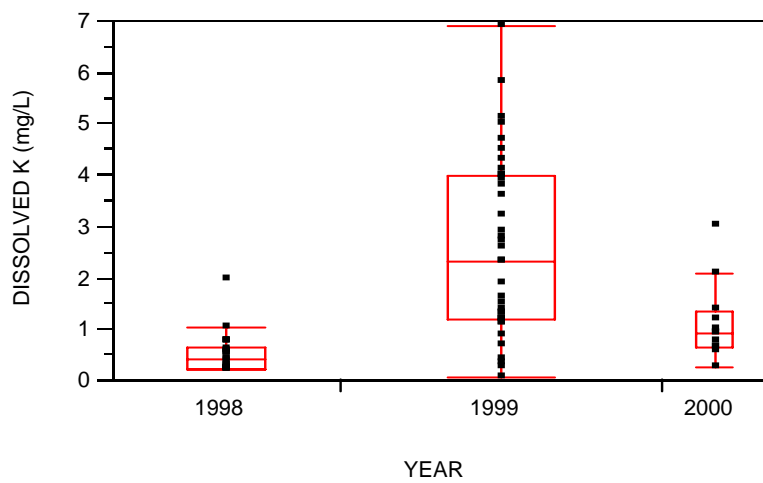
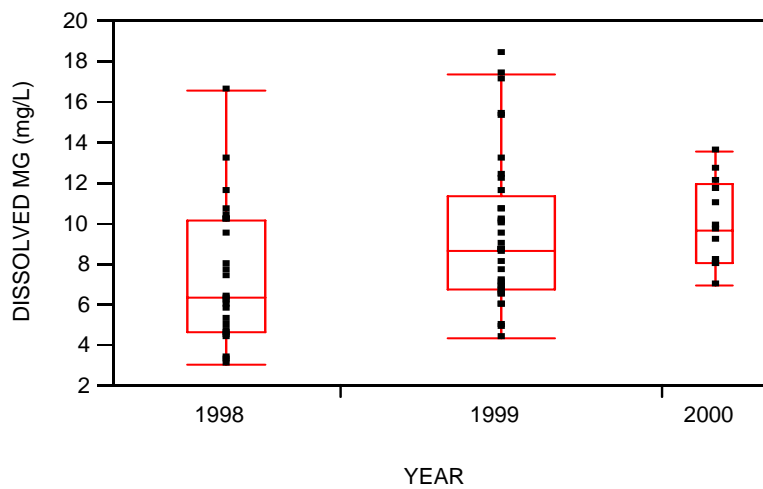
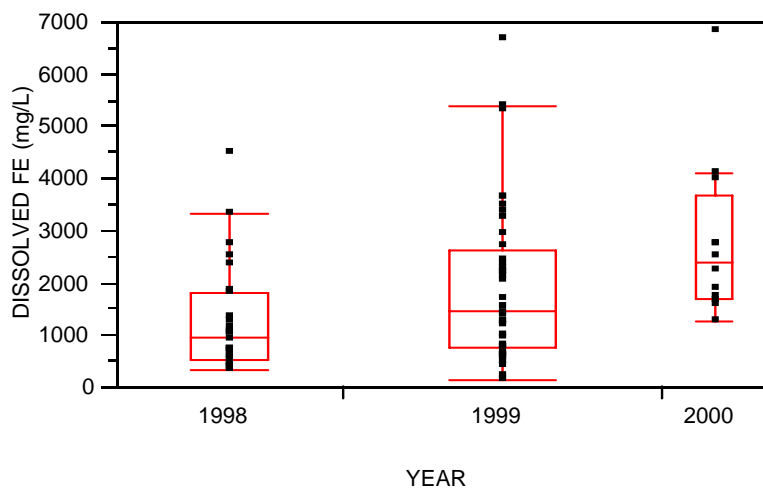
APPENDIX IIA – INSERT HERE.

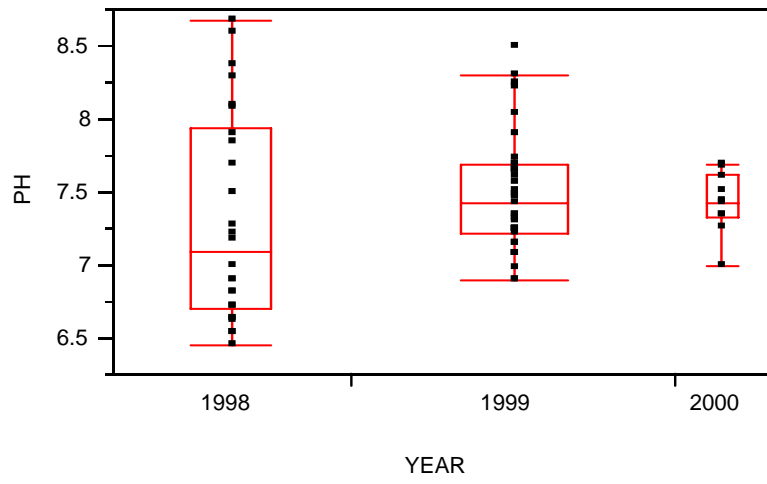
**Appendix IIB.** Graphs comparing yearly mean pore water quality concentrations for the Rotenberger Wildlife Management Area during the pre-discharge period (November 1997 through June 2001). Appendix II contains graphs of the following parameters: dissolved TKN, dissolved nitrate/nitrite, dissolved NH<sub>3</sub>, dissolved organic C, dissolved Cl, dissolved SO<sub>4</sub>, dissolved Si, dissolved Ca, dissolved Fe, dissolved Mg, dissolved K, and pH.











**Appendix III-A.** List and frequency of occurrence of species present in the periphyton analyzed during the pre-discharge periods within the Rotenberger Wildlife Management Area. The pre-discharge period extends from November 1997 through June 2001.

| <b>Genus/Species Pre-Discharge Period</b> | <b>Frequency</b> |
|---|------------------|
| Achnanthes                                | 9                |
| Achnanthidium minutissimum                | 9                |
| Anabaena                                  | 27               |
| Anabaena levanderi                        | 3                |
| Anomoeoneis                               | 2                |
| Aphanocapsa                               | 11               |
| Aphanochaete                              | 3                |
| Aphanochaete repens                       | 1                |
| Aphanothece                               | 6                |
| Aphanothece nidulans                      | 1                |
| Aulacoseira granulata                     | 1                |
| Bacillariophyceae                         | 11               |
| Brachysira serians                        | 1                |
| Brachysira vitrea                         | 10               |
| Bulbochaete                               | 13               |
| Calothrix                                 | 6                |
| Chaetophora                               | 1                |
| Chaetosphaeridium                         | 1                |
| Chaetosphaeridium globosum                | 2                |
| Chamaecalyx swirenkoi                     | 3                |
| Characium                                 | 8                |
| Chlamydocapsa planctonica                 | 10               |
| Chlamydomonas                             | 22               |
| Chlorella                                 | 34               |
| Chlorococcaceae                           | 6                |
| Chlorococcum                              | 14               |
| Chlorophyceae                             | 1                |
| Chroococcaceae                            | 1                |
| Chroococcus                               | 16               |
| Chroococcus minutus                       | 16               |
| Chroococcus turgidus                      | 3                |
| Chroococcus varius                        | 1                |
| Closteriopsis                             | 1                |
| Closterium                                | 6                |

**Appendix III-A cont.** List and frequency of occurrence of species present in the periphyton analyzed during the pre-discharge periods within the Rotenberger Wildlife Management Area. The pre-discharge period extends from November 1997 through June 2001.

| <b>Genus/Species Pre-Discharge Period</b> | <b>Frequency</b> |
|---|------------------|
| Closterium diana                          | 4                |
| Coelastrum                                | 9                |
| Coelastrum cambricum                      | 4                |
| Coleochaete                               | 6                |
| Coleochaete orbicularis                   | 1                |
| Cosmarium                                 | 16               |
| Cosmarium adoxum                          | 1                |
| Cosmarium anisochondrum                   | 1                |
| Cosmarium bioculatum                      | 3                |
| Cosmarium calcareum                       | 5                |
| Cosmarium contractum                      | 2                |
| Cosmarium pyramidatum                     | 1                |
| Cosmarium regnellii                       | 3                |
| Cosmarium regnellii minimum               | 2                |
| Cosmarium variolatum                      | 1                |
| Craticula accomoda                        | 1                |
| Craticula cuspidata                       | 7                |
| Crucigenia                                | 3                |
| Cyanobium parvum                          | 18               |
| Cyanothece aeruginosa                     | 2                |
| Cyclotella                                | 9                |
| Cylindrospermum                           | 5                |
| Cymbella                                  | 1                |
| Cymbella microcephala                     | 4                |
| Cymbellaceae                              | 3                |
| Dactylococcopsis                          | 13               |
| Derepyxis amphora                         | 1                |
| Desmidium aptogonum                       | 2                |
| Desmococcus viridis                       | 1                |
| Dinobryon                                 | 3                |
| Diploneis                                 | 2                |
| Diploneis ovalis                          | 1                |
| Diploneis pseudovalis                     | 2                |
| Draparnaldia                              | 2                |
| Encyonema evergladianum                   | 2                |
| Encyonema minutum                         | 2                |
| Encyonema minutum pseudogracil            | 3                |

**Appendix III-A cont.** List and frequency of occurrence of species present in the periphyton analyzed during the pre-discharge periods within the Rotenberger Wildlife Management Area. The pre-discharge period extends from November 1997 through June 2001.

| <b>Genus/Species Pre-Discharge Period</b> | <b>Frequency</b> |
|---|------------------|
| Encyonema silesiacum                      | 10               |
| Encyonopsis subminuta                     | 1                |
| Euastrum                                  | 1                |
| Euastrum bidentatum oculatum              | 1                |
| Euastrum turneri stictum                  | 1                |
| Euglena                                   | 2                |
| Eunotia                                   | 16               |
| Eunotia exigua                            | 1                |
| Eunotia flexuosa eurycephala              | 2                |
| Eunotia glacialis                         | 9                |
| Eunotia naegeli                           | 1                |
| Fortiea                                   | 1                |
| Fragilaria                                | 4                |
| Fragilaria crotonensis                    | 1                |
| Fragilariaceae                            | 6                |
| Geminella                                 | 1                |
| Glenodinium                               | 5                |
| Gloeocapsa                                | 6                |
| Gloeocapsa decorticans                    | 1                |
| Gloeocapsa polydermatica                  | 1                |
| Gloeochaete                               | 1                |
| Gloeocystis                               | 6                |
| Gloeotheca                                | 3                |
| Gomphonema                                | 23               |
| Gomphonema affine                         | 7                |
| Gomphonema clavatum                       | 1                |
| Gomphonema gracile                        | 23               |
| Gomphonema parvulum                       | 27               |
| Gomphonema vibrio intricatum              | 2                |
| Gonatozygon                               | 4                |
| Hapalosiphon                              | 1                |
| Kirchneriella                             | 2                |
| Lagynion macrotrachelum                   | 8                |
| Luticola mutica                           | 3                |
| Lyngbya                                   | 34               |
| Lyngbya aerugineo-caerulea                | 9                |
| Lyngbya birgei                            | 3                |

**Appendix III-A cont.** List and frequency of occurrence of species present in the periphyton analyzed during the pre-discharge periods within the Rotenberger Wildlife Management Area. The pre-discharge period extends from November 1997 through June 2001.

| <b>Genus/Species Pre-Discharge Period</b> | <b>Frequency</b> |
|---|------------------|
| Mastogloia                                | 2                |
| Mastogloia pumila                         | 3                |
| Merismopedia                              | 7                |
| Merismopedia punctata                     | 1                |
| Merismopedia tenuissima                   | 5                |
| Merismopediaceae                          | 1                |
| Micrasterias                              | 1                |
| Microchaete                               | 4                |
| Microcystis                               | 11               |
| Monoraphidium contortum                   | 15               |
| Mougeotia                                 | 25               |
| Navicula                                  | 5                |
| Navicula cryptocephala                    | 8                |
| Navicula cryptotenella                    | 4                |
| Navicula digitoradiata                    | 1                |
| Navicula radiosa                          | 4                |
| Navicula trivialis                        | 1                |
| Nitzschia                                 | 13               |
| Nitzschia amphibia                        | 14               |
| Nitzschia gracilis                        | 7                |
| Nitzschia nana                            | 3                |
| Nitzschia palea                           | 28               |
| Oedogonium                                | 32               |
| Onychonema laeve latum                    | 2                |
| Oocystis                                  | 8                |
| Ophiocytium capitatum                     | 1                |
| Ophiocytium parvulum                      | 2                |
| Oscillatoria                              | 34               |
| Oscillatoria acutissima                   | 2                |
| Oscillatoria granulata                    | 2                |
| Oscillatoria minima                       | 3                |
| Oscillatoria subbrevis                    | 1                |
| Pediastrum duplex                         | 1                |
| Pediastrum obtusum                        | 1                |
| Pediastrum tetras                         | 1                |
| Phacus                                    | 5                |
| Phormidium formosum                       | 3                |

**Appendix III-A cont.** List and frequency of occurrence of species present in the periphyton analyzed during the pre-discharge periods within the Rotenberger Wildlife Management Area. The pre-discharge period extends from November 1997 through June 2001.

| <b>Genus/Species Pre-Discharge Period</b> | <b>Frequency</b> |
|---|------------------|
| Pinnularia                                | 10               |
| Placoneis clementis                       | 1                |
| Planktolingbya subtilis                   | 1                |
| Planktothrix agardhii                     | 1                |
| Plectonema                                | 1                |
| Protoderma                                | 1                |
| Pseudanabaena limnetica                   | 3                |
| Raciborskia bicornis                      | 1                |
| Rhabdoderma                               | 4                |
| Rhabdogloea smithii                       | 2                |
| Rhopalodia gibba                          | 2                |
| Rossithidium linearis                     | 1                |
| Scenedesmus                               | 18               |
| Scenedesmus abundans                      | 1                |
| Scenedesmus arcuatus                      | 1                |
| Scenedesmus brasiliensis                  | 9                |
| Scenedesmus dimorphus                     | 4                |
| Scenedesmus ellipticus                    | 17               |
| Scenedesmus incrassatulus                 | 5                |
| Scenedesmus quadricauda                   | 17               |
| Scytonema                                 | 3                |
| Selenastrum                               | 18               |
| Sellaphora pupula                         | 12               |
| Sorastrum americanum                      | 1                |
| Spirogyra                                 | 8                |
| Spirulina laxa                            | 1                |
| Spirulina subsalsa                        | 1                |
| Staurastrum                               | 6                |
| Staurastrum cyrtocentrum                  | 2                |
| Staurastrum excavatum minimum             | 1                |
| Stauroneis anceps                         | 2                |
| Stigeoclonium                             | 16               |
| Synechococcaceae                          | 1                |
| Synechococcus                             | 14               |
| Synedra                                   | 1                |
| Synedra delicatissima                     | 10               |
| Tetraedron caudatum                       | 2                |

**Appendix III-A cont.** List and frequency of occurrence of species present in the periphyton analyzed during the pre-discharge periods within the Rotenberger Wildlife Management Area. The pre-discharge period extends from November 1997 through June 2001.

| <b>Genus/Species Pre-Discharge Period</b> | <b>Frequency</b> |
|---|------------------|
| Tetraedron minimum                        | 9                |
| Tetraedron muticum                        | 3                |
| Trachelomonas                             | 3                |
| Ulothrix                                  | 3                |
| Zygnema                                   | 1                |

**Appendix III-B.** List and frequency of occurrence of species present in the periphyton analyzed during the post-discharge periods within the Rotenberger Wildlife Management Area. The post-discharge period extends from July 2001 through June 2003.

| <b>Genus/Species Post-Discharge Period</b> | <b>Frequency</b> |
|--|------------------|
| Achnanthes                                 | 10               |
| Achnanthidium exiguum                      | 5                |
| Achnanthidium minutissimum                 | 10               |
| Amphora                                    | 1                |
| Anabaena                                   | 26               |
| Ankistrodesmus                             | 1                |
| Anomoeoneis                                | 2                |
| Aphanocapsa                                | 5                |
| Aphanochaete                               | 1                |
| Aphanochaete repens                        | 1                |
| Aphanothece                                | 1                |
| Aphanothece microscopica                   | 1                |
| Aulacoseira                                | 1                |
| Bacillaria paxillifer                      | 5                |
| Bacillariophyceae                          | 7                |
| Brachysira                                 | 3                |
| Brachysira serians                         | 1                |
| Brachysira vitrea                          | 14               |
| Bulbochaete                                | 10               |
| Caloneis bacillum                          | 1                |
| Calothrix                                  | 15               |
| Calothrix braunii                          | 1                |
| Chaetosphaeridium globosum                 | 3                |
| Characium                                  | 15               |
| Characium ambiguum                         | 2                |
| Chlamydocapsa planctonica                  | 7                |
| Chlamydomonas                              | 14               |
| Chlorella                                  | 22               |
| Chlorococcum                               | 12               |
| Chlorophyceae                              | 3                |
| Chroococcaceae                             | 2                |
| Chroococciopsis                            | 1                |
| Chroococcus                                | 1                |
| Chroococcus minimus                        | 1                |
| Chroococcus minutus                        | 5                |
| Chroococcus pallidus                       | 2                |

**Appendix III-B cont.** List and frequency of occurrence of species present in the periphyton analyzed during the post-discharge periods within the Rotenberger Wildlife Management Area. The post-discharge period extends from July 2001 through June 2003.

| <b>Genus/Species Post-Discharge Period</b> | <b>Frequency</b> |
|--|------------------|
| Chroococcus turgidus                       | 3                |
| Closterium                                 | 1                |
| Closterium gracile                         | 2                |
| Closterium venus                           | 1                |
| Cocconeis                                  | 1                |
| Cocconeis placentula                       | 1                |
| Coelastrum                                 | 2                |
| Coleochaete                                | 1                |
| Coleochaete orbicularis                    | 2                |
| Cosmarium                                  | 4                |
| Cosmarium abbreviatum minus                | 1                |
| Cosmarium bioculatum                       | 1                |
| Cosmarium calcareum                        | 1                |
| Cosmarium phaseolus                        | 1                |
| Cosmarium pseudoretusum inaequ             | 1                |
| Craticula cuspidata                        | 1                |
| Crucigenia                                 | 1                |
| Cyanobium parvum                           | 26               |
| Cyanobium plancticum                       | 18               |
| Cyanothece                                 | 1                |
| Cyanothece aeruginosa                      | 1                |
| Cyclotella                                 | 14               |
| Cyclotella meneghiniana                    | 3                |
| Cyclotella striata                         | 1                |
| Cylindrospermum                            | 18               |
| Cymbella microcephala                      | 7                |
| Cymbellaceae                               | 7                |
| Dactylococcus                              | 1                |
| Derepyxis amphora                          | 3                |
| Diadesmis confervacea                      | 2                |
| Dinobryon                                  | 4                |
| Dinobryon sertularia                       | 4                |
| Dinobryon sociale                          | 1                |
| Diploneis                                  | 6                |
| Diploneis ovalis                           | 6                |
| Elakatothrix gelatinosa                    | 1                |
| Elakatothrix viridis                       | 1                |

**Appendix III-B cont.** List and frequency of occurrence of species present in the periphyton analyzed during the post-discharge periods within the Rotenberger Wildlife Management Area. The post-discharge period extends from July 2001 through June 2003.

| <b>Genus/Species Post-Discharge Period</b> | <b>Frequency</b> |
|--|------------------|
| Encyonema                                  | 1                |
| Encyonema evergladianum                    | 6                |
| Encyonema neomesianum                      | 6                |
| Encyonema silesiacum                       | 4                |
| Euastrum insulare                          | 1                |
| Eunotia                                    | 24               |
| Eunotia flexuosa eurycephala               | 2                |
| Eunotia glacialis                          | 1                |
| Eunotia naegelii                           | 1                |
| Fortiea bossei                             | 4                |
| Fragilaria                                 | 1                |
| Fragilaria synegrotesca                    | 3                |
| Fragilariaceae                             | 22               |
| Glenodinium                                | 7                |
| Gloeocapsa                                 | 1                |
| Gloeocystis                                | 7                |
| Gloeotheca                                 | 2                |
| Gomphonema                                 | 22               |
| Gomphonema affine                          | 3                |
| Gomphonema gracile                         | 21               |
| Gomphonema grovei                          | 1                |
| Gomphonema parvulum                        | 16               |
| Gymnodinium                                | 1                |
| Jaaginema                                  | 9                |
| Kentrosphaera                              | 1                |
| Kephyrion                                  | 6                |
| Lagynion                                   | 1                |
| Lagynion ampullaceum                       | 1                |
| Lagynion macrotrachelum                    | 10               |
| Lagynion reductum                          | 3                |
| Lepocinclis                                | 2                |
| Lyngbya                                    | 21               |
| Lyngbya aerugineo-caerulea                 | 6                |
| Lyngbya lagerheimii                        | 1                |
| Lyngbya taylorii                           | 1                |
| Mastogloia                                 | 2                |
| Mastogloia smithii                         | 1                |

**Appendix III-B cont.** List and frequency of occurrence of species present in the periphyton analyzed during the post-discharge periods within the Rotenberger Wildlife Management Area. The post-discharge period extends from July 2001 through June 2003.

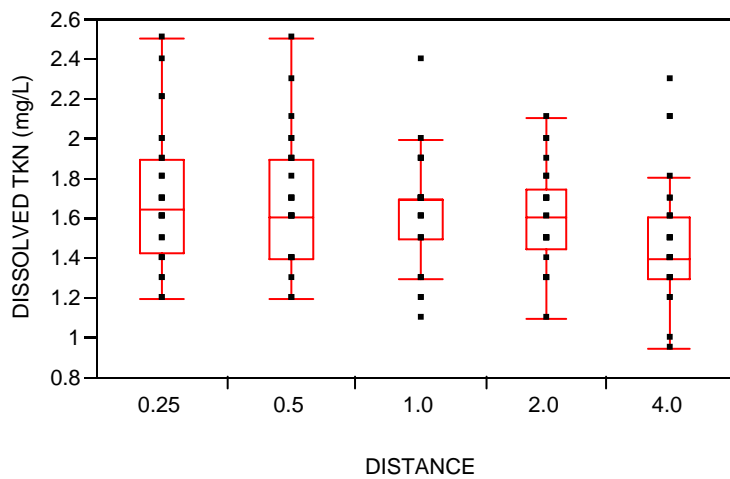
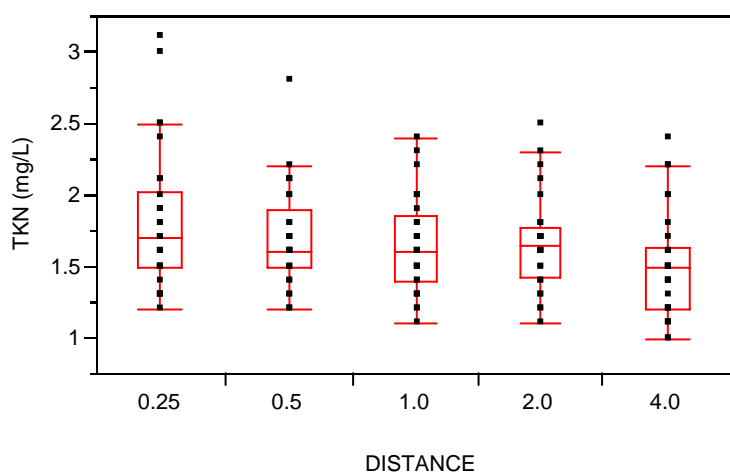
| <b>Genus/Species Post-Discharge Period</b> | <b>Frequency</b> |
|--|------------------|
| Merismopedia                               | 1                |
| Merismopedia minima                        | 1                |
| Microchaete                                | 2                |
| Microchaete tenera                         | 1                |
| Microcystis                                | 7                |
| Monoraphidium contortum                    | 4                |
| Mougeotia                                  | 20               |
| Navicula                                   | 5                |
| Navicula cryptocephala                     | 14               |
| Navicula cryptotenella                     | 3                |
| Navicula radiosa                           | 1                |
| Nitzschia                                  | 26               |
| Nitzschia amphibia                         | 23               |
| Nitzschia fonticola                        | 1                |
| Nitzschia frustulum                        | 3                |
| Nitzschia gracilis                         | 11               |
| Nitzschia nana                             | 16               |
| Nitzschia obtusa                           | 4                |
| Nitzschia palea                            | 19               |
| Nitzschia reversa                          | 1                |
| Oedogonium                                 | 24               |
| Onychonema laeve latum                     | 1                |
| Oocystis                                   | 7                |
| Ophiocytium cochleare                      | 2                |
| Ophiocytium elongatum                      | 1                |
| Ophiocytium gracilipes                     | 1                |
| Ophiocytium parvulum                       | 1                |
| Oscillatoria                               | 21               |
| Oscillatoria acutissima                    | 1                |
| Oscillatoria limosa                        | 1                |
| Oscillatoria subbrevis                     | 1                |
| Pennales                                   | 7                |
| Phacus                                     | 4                |
| Phormidium formosum                        | 1                |
| Pinnularia                                 | 8                |
| Planktolyngbya                             | 9                |
| Planktothrix agardhii                      | 5                |
| Pleurotaenium minutum                      | 1                |

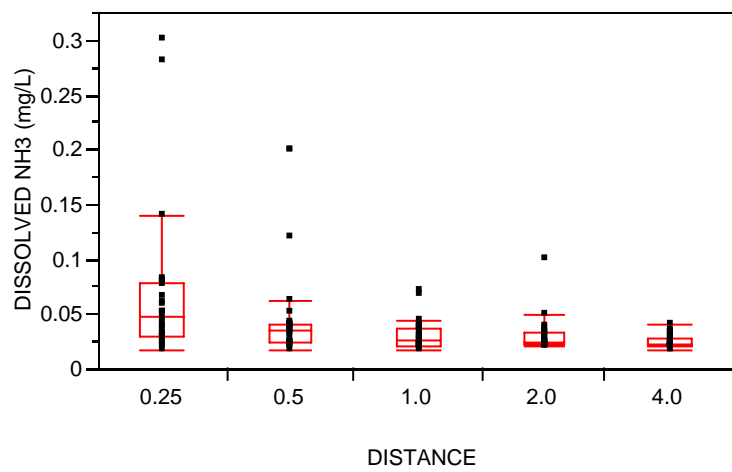
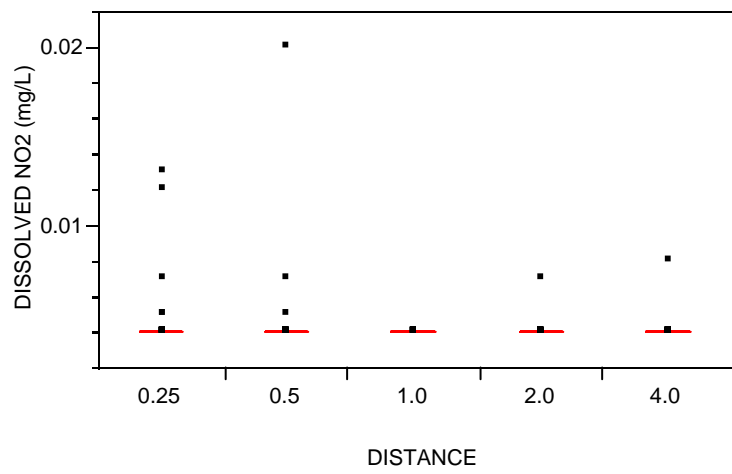
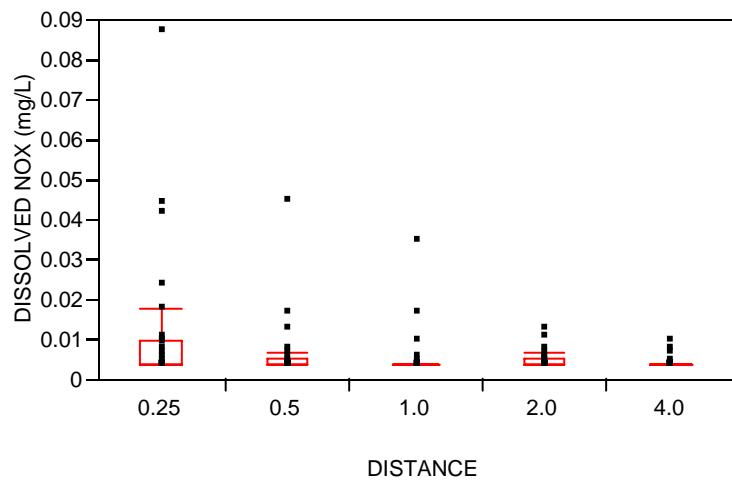
**Appendix III-B cont.** List and frequency of occurrence of species present in the periphyton analyzed during the post-discharge periods within the Rotenberger Wildlife Management Area. The post-discharge period extends from July 2001 through June 2003.

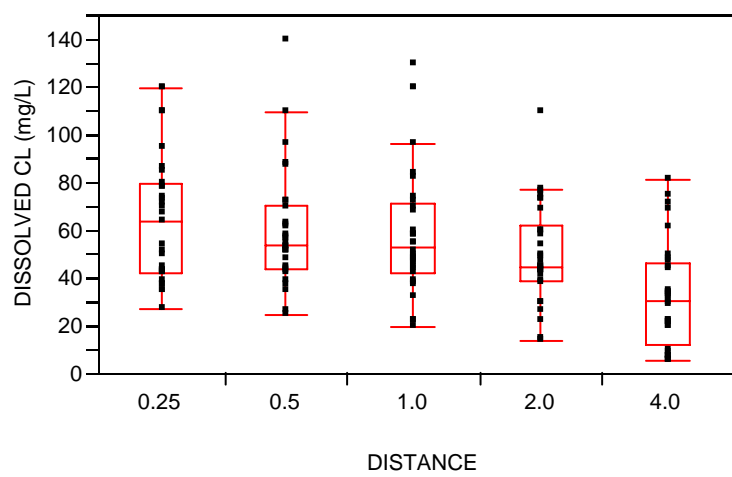
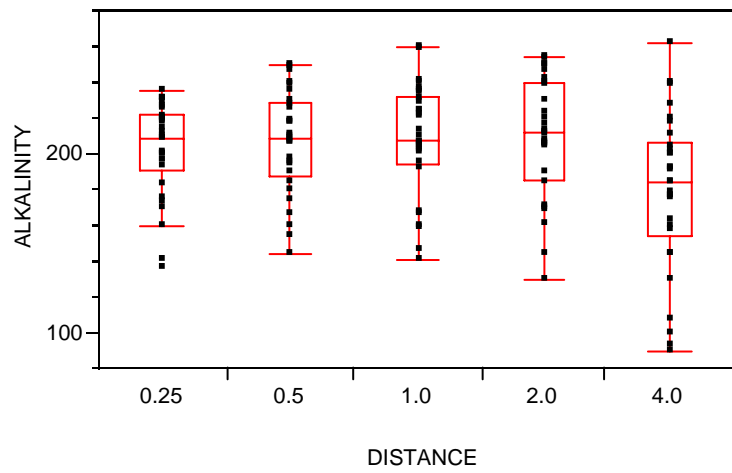
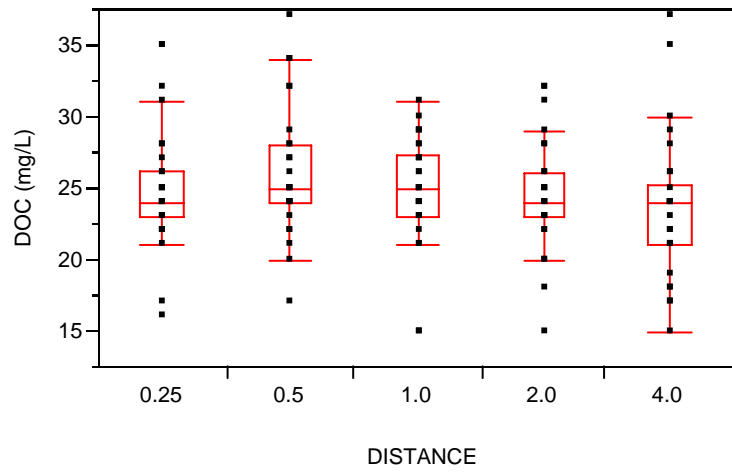
| <b>Genus/Species Post-Discharge Period</b> | <b>Frequency</b> |
|--|------------------|
| Protococcus                                | 1                |
| Pseudanabaena limnetica                    | 9                |
| Raciborskia bicornis                       | 1                |
| Rhabdogloea                                | 1                |
| Rhabdogloea smithii                        | 1                |
| Rhopalodia gibba                           | 14               |
| Scenedesmus                                | 3                |
| Scenedesmus ellipticus                     | 8                |
| Scenedesmus quadricauda                    | 1                |
| Scytonema                                  | 3                |
| Selenastrum                                | 4                |
| Sellaphora pupula                          | 3                |
| Spirogyra                                  | 3                |
| Staurastrum                                | 4                |
| Staurastrum brachioprominens               | 1                |
| Staurastrum cyathipes                      | 1                |
| Staurastrum cyrtocerum                     | 1                |
| Stauroneis javanica                        | 1                |
| Stigeoclonium                              | 14               |
| Synechocystis                              | 6                |
| Synedra                                    | 3                |
| Synedra delicatissima                      | 5                |
| Synedra ulna                               | 8                |
| Tetraedron minimum                         | 5                |
| Tetraedron muticum                         | 1                |
| Trachelomonas                              | 10               |
| Xanthidium                                 | 1                |

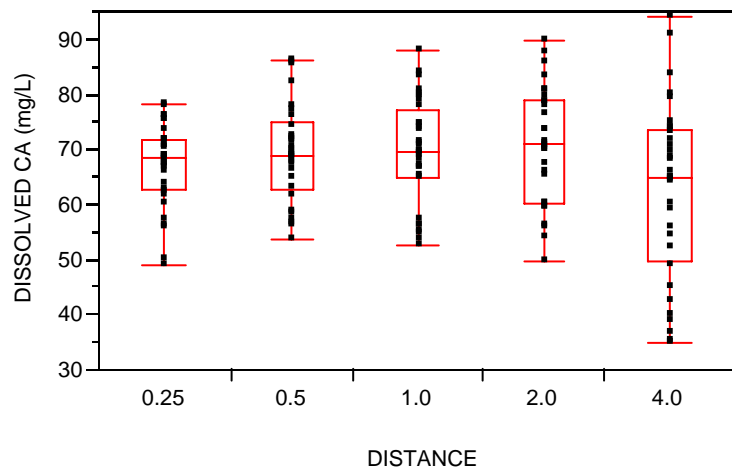
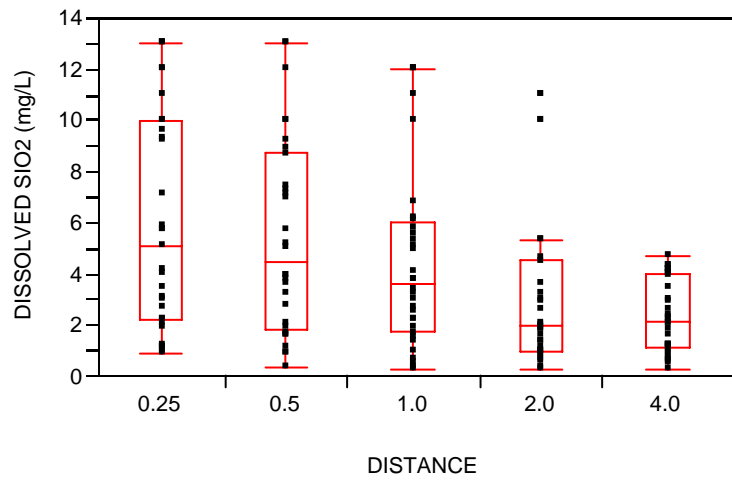
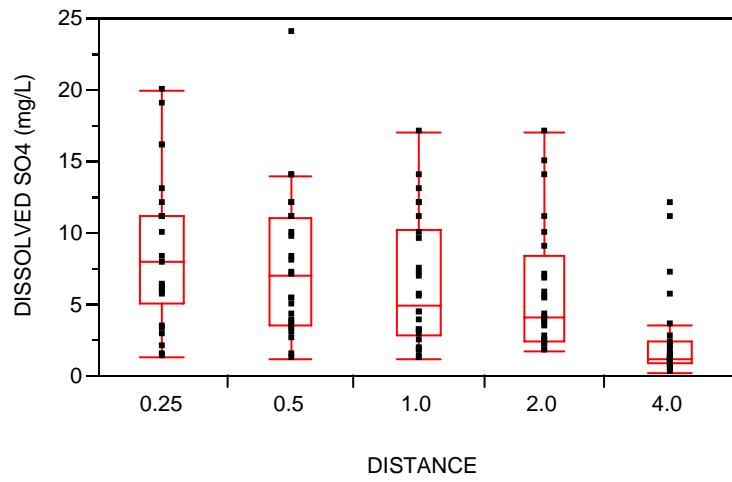
INSERT APPENDIX IVA HERE

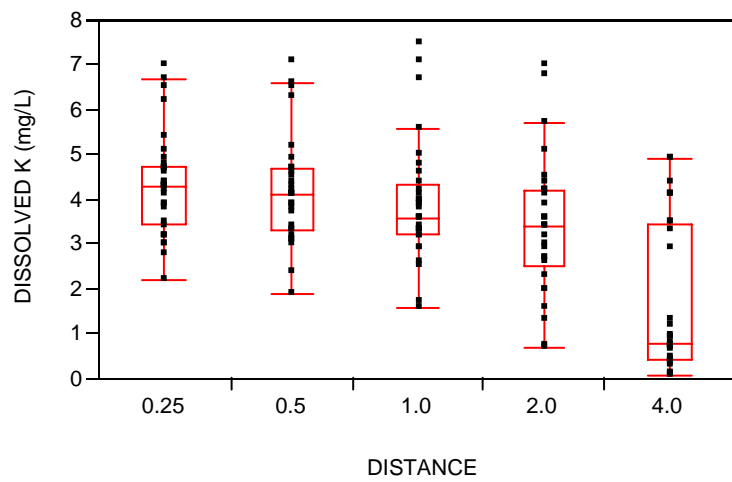
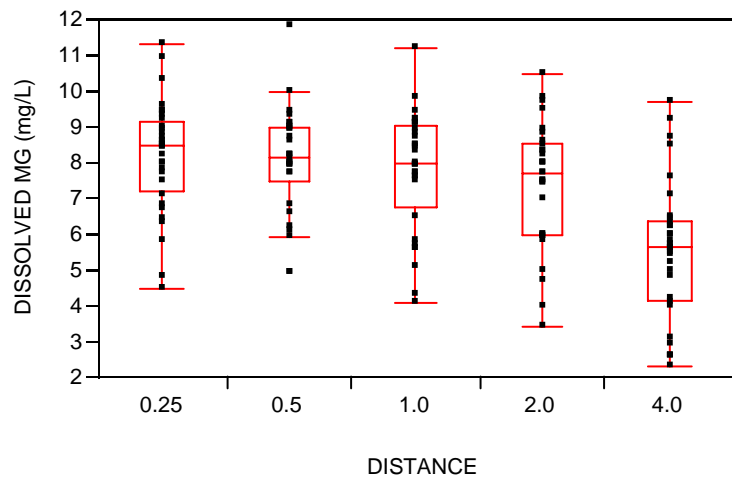
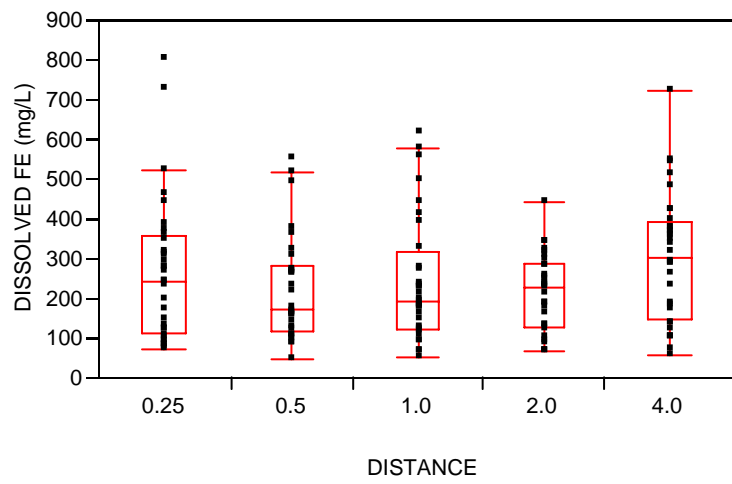
**Appendix IVB:** Graphs comparing mean surface water quality concentrations along a spatial gradient extending 4 km from the inflow into the Rotenberger Wildlife Management Area during the post-discharge period (July 2001 through June 2003). Appendix IV contains graphs of the following parameters: TKN, dissolved TKN, dissolved nitrate/nitrite, dissolved NO<sub>2</sub>, dissolved NH<sub>3</sub>, dissolved organic C, alkalinity, dissolved Cl, dissolved SO<sub>4</sub>, dissolved Si, dissolved Ca, dissolved Fe, dissolved Mg, dissolved K, dissolved Na, dissolved oxygen, temperature, specific conductance, and pH.

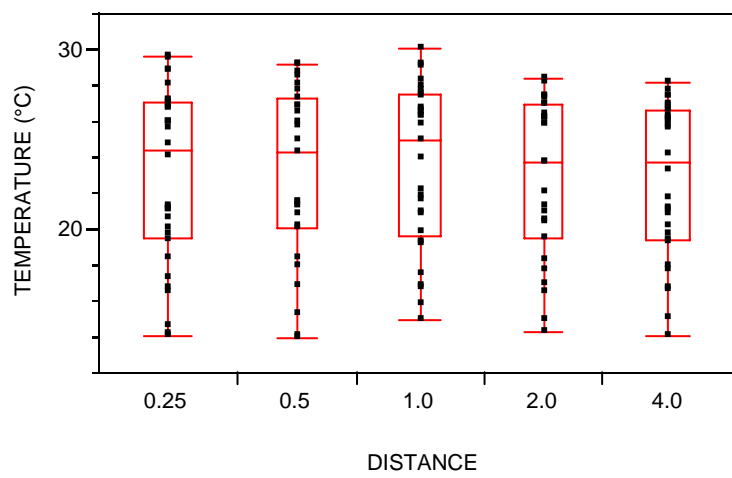
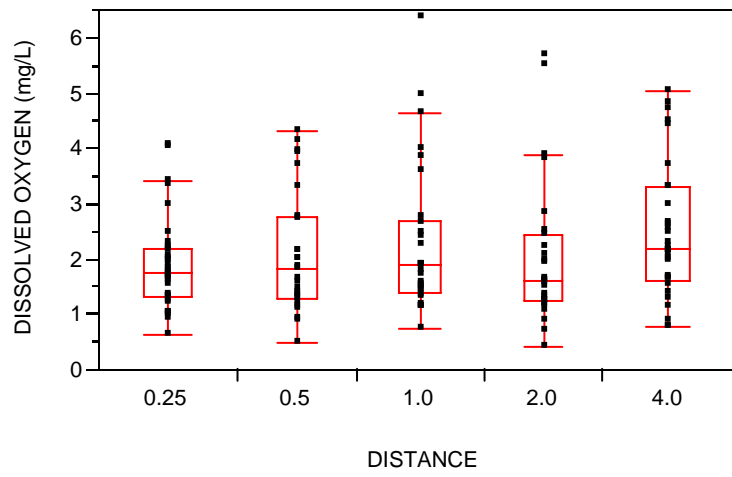
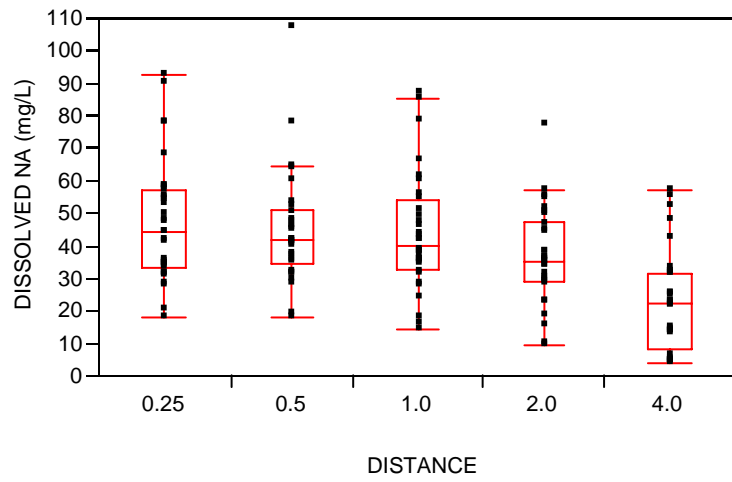


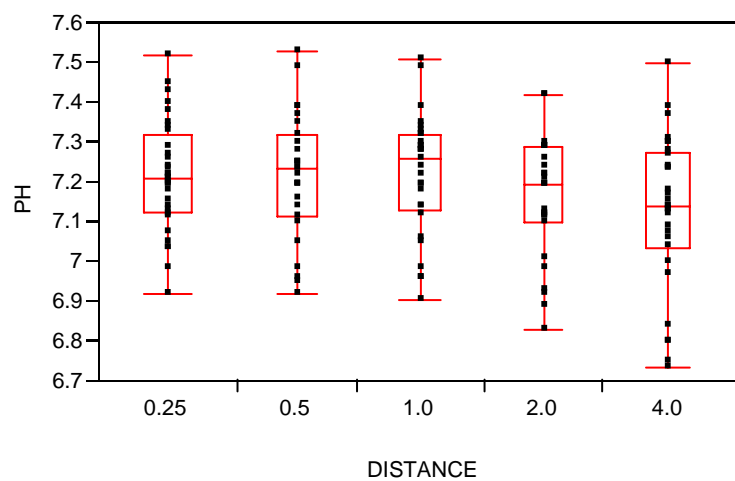
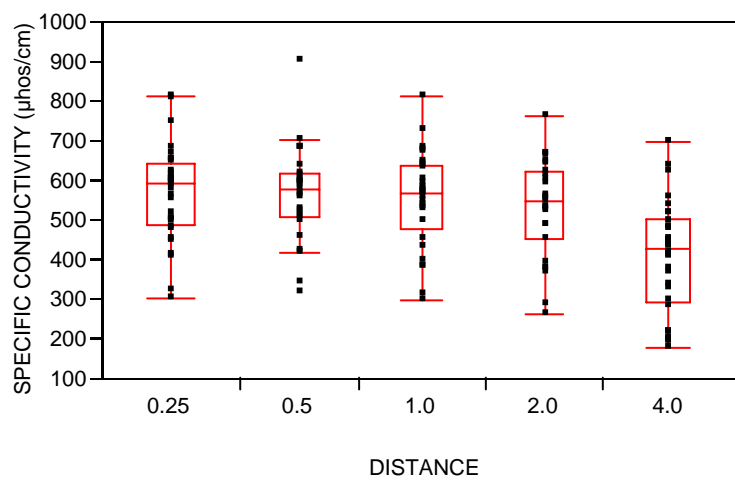








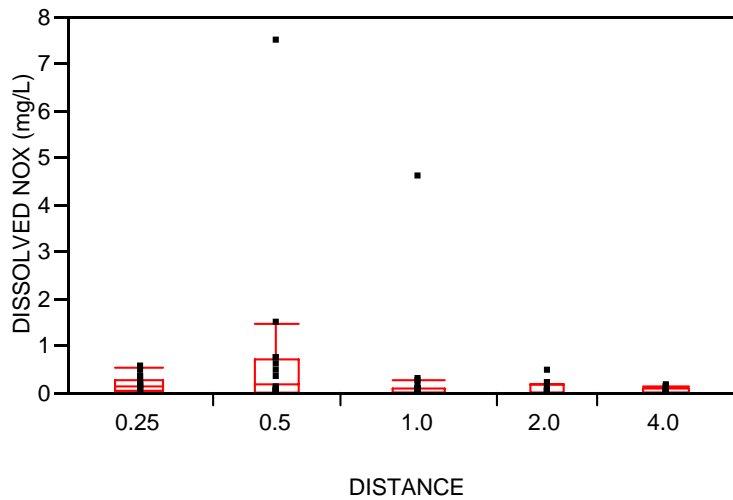
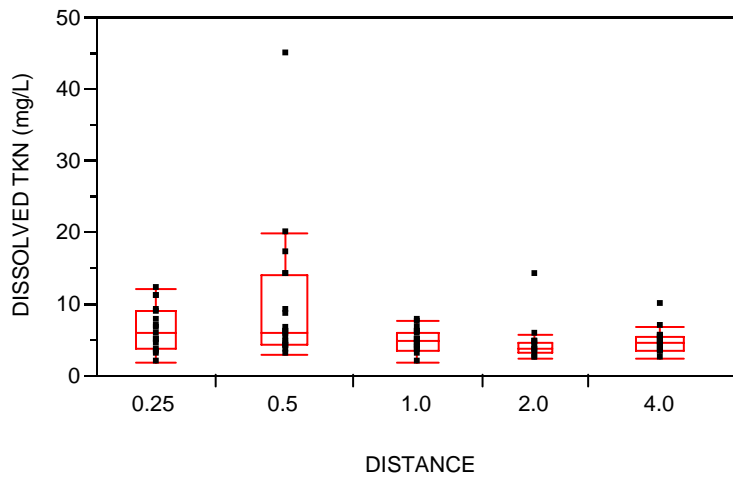


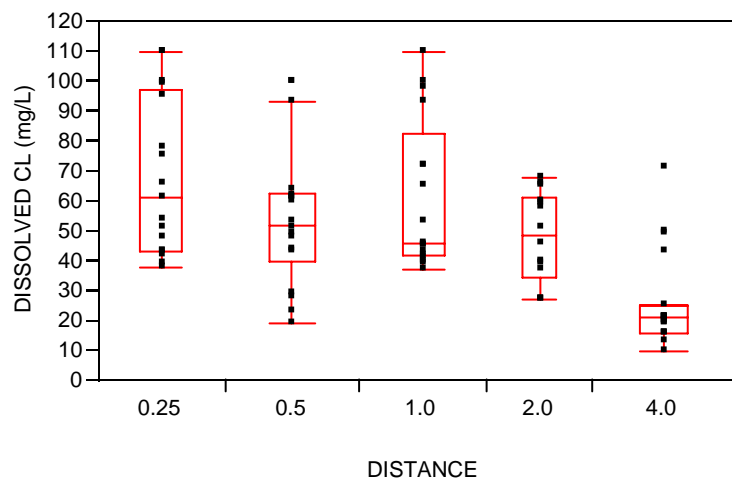
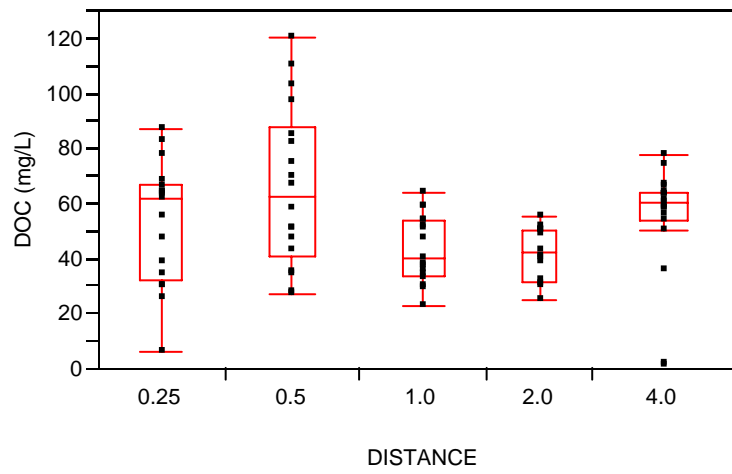
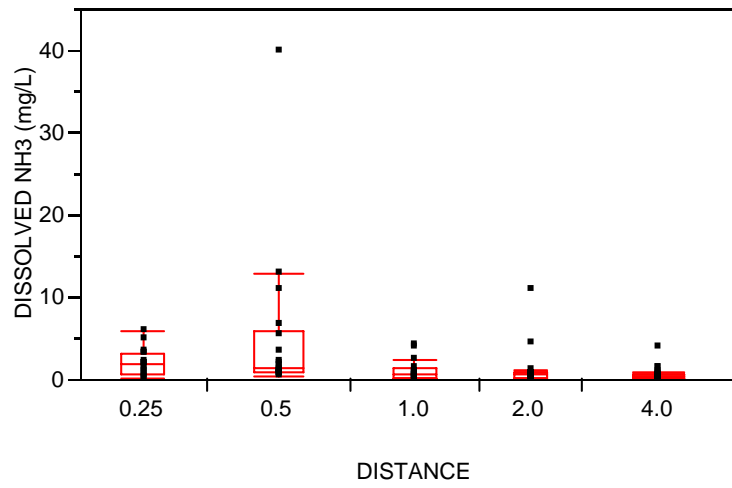


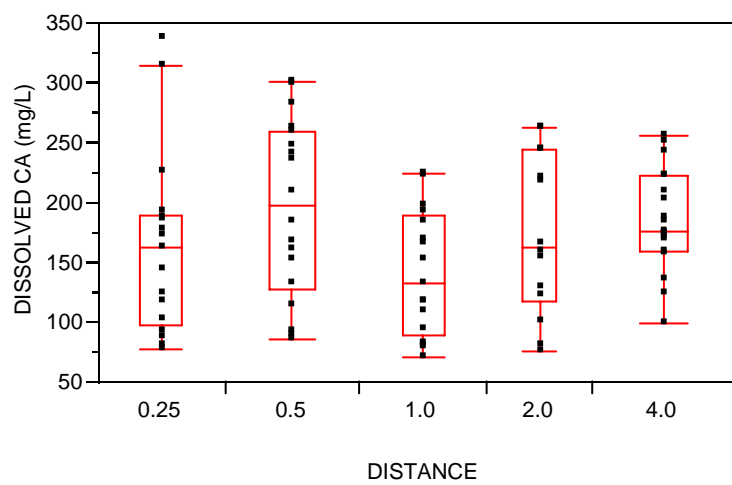
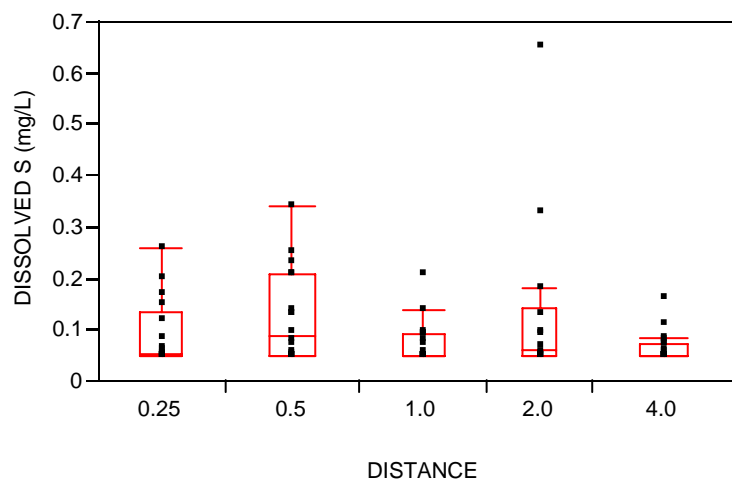
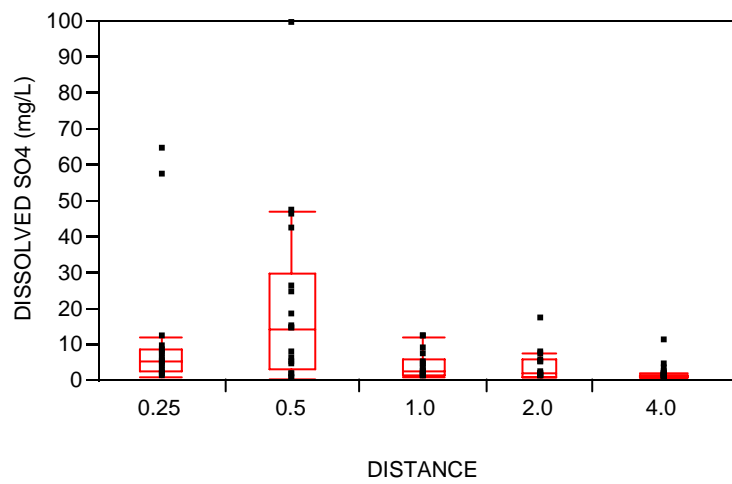
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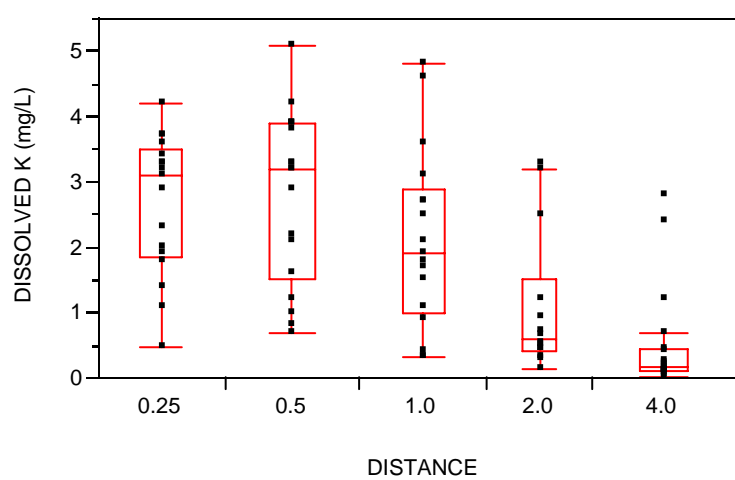
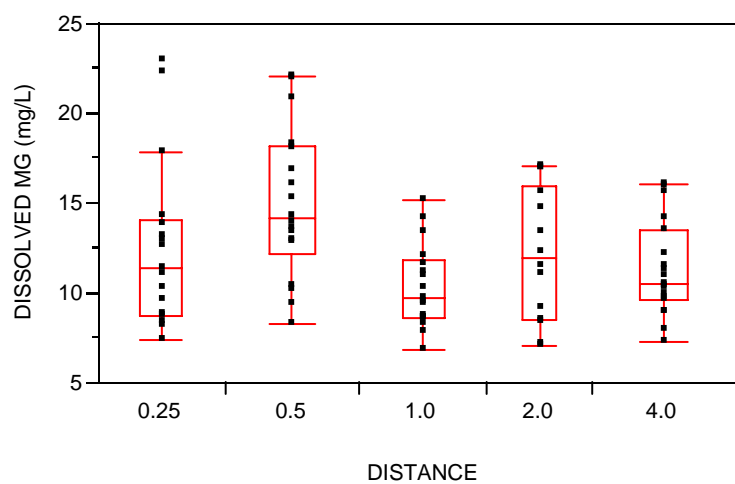
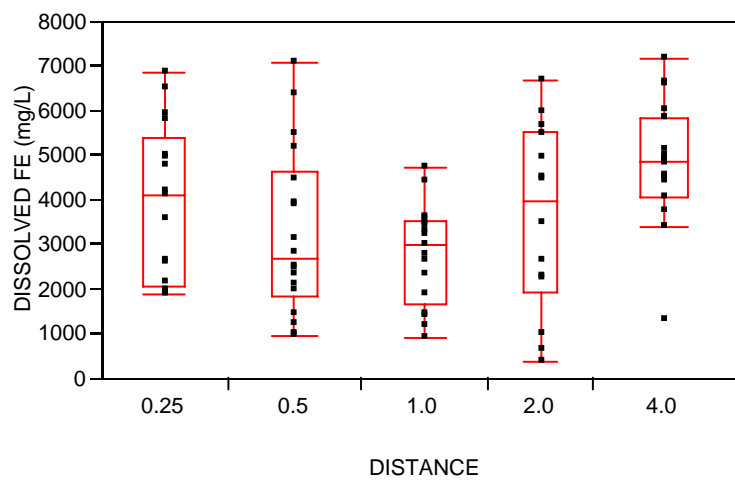
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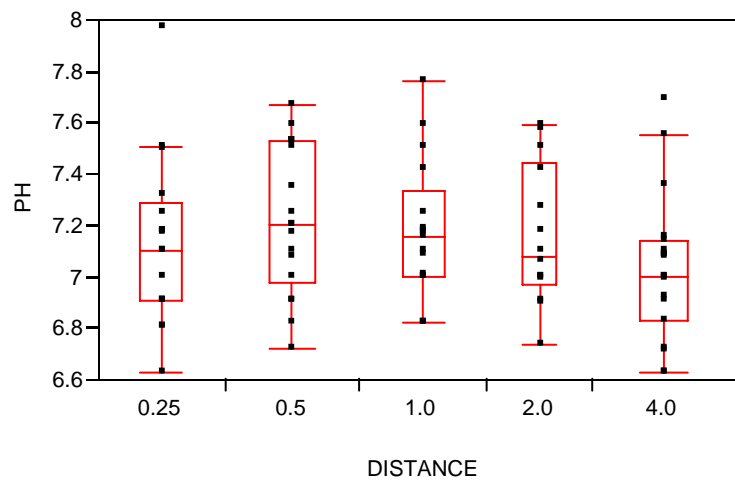
**Appendix VB.** Graphs comparing mean pore water quality concentrations along a spatial gradient extending 4 km from the inflow into the Rotenberger Wildlife Management Area during the post-discharge period (July 2001 through June 2003). Appendix V contains graphs of the following parameters: dissolved TKN, dissolved nitrate/nitrite, dissolved NH<sub>3</sub>, dissolved organic C, dissolved Cl, dissolved SO<sub>4</sub>, dissolved Si, dissolved Ca, dissolved Fe, dissolved Mg, dissolved K, and pH.











Attach Appendix VC

## **APPENDIX VI. Proposed monitoring program for the Rotenberger Wildlife Management Area.**

The initial Northern and Southern transects were grouped in close proximity to the inflow source and did not extend farther than 4.0 km into the marsh, providing a very limited areal assessment of discharge effects. The initial objective of these transects was to document any short-term biological (vegetative community) and geo-chemical (water and sediment nutrient) changes that occurred as a direct result of STA discharges. However, this limited areal monitoring extent will not provide an overall assessment of ecosystem response to downstream discharge. Therefore, we propose retaining the sampling sites closest to the point of discharge (0.25 and 0.5 km), while extending the transect trajectory across the marsh with sites located mid-marsh and towards the outflow. Based on the findings presented in this report, we propose a reduction in the number of water quality parameters analyzed, in addition to reducing the frequency of sediment and vegetation collection. However, by extending the transect to incorporate a greater portion of the RWMA , we will be able to collect the information necessary to quantify any overall indirect ecosystem effects of STA discharge, as well as continue to monitor the short-term direct effects expected closer to the discharge site. Vegetation sampling that includes species richness in concert with vegetation maps will enable us to document the expected expansion of wetland plants throughout the entire tract. Soil nutrient concentration will be analyzed every two years in an effort to capture large-scale changes in this nutrient storage compartment. Also, in an effort to provide phosphorus flux rate coefficients to support modeling efforts, we are investigating a means to measure in-site sediment phosphorus flux rates directly downstream of the STA discharges.